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THE RECENT SURVEY OF ST. LOUIS,—ITS METHODS AND RESULTS.

By B. H. COLBY, 1st. Asst. Engineer, in Charge of Surveys, Sewer Department, St. Louis, Mo., Member Engineers' Club of St. Louis.

[Read November 2, 1892.]

The authority for making the surveys, to be spoken of this evening, is fouud in City Ordinance, No. 14,846, approved March 21, 1889, and entitled: "An ordinance to authorize surveys for the purpose of perfecting plans for the drainage of the city, and other purposes."

SECTION 1. "The Board of Public Improvements is hereby authorized and directed to cause surveys to be made, of those portions of the city for which drainage or sewer plans have not been made hitherto, or for which the plans heretofore made are now deemed inadequate.

Said surveys shall be so made and mapped as to be useful for locating and opening streets, alleys, and for establishing grades for streets and public places."

SEC. 2, designates the number of employes, salary etc.

SEC. 3, is as follows: "The surveys, maps and plans herein authorized to be made shall be executed under the supervision of the Sewer Commissioner, who shall appoint the employes herein authorized, subject to the approval of the President of the Board of Public Improvements. In carrying out the provisions of this ordinance the Sewer Commissioner shall give attention, first, to the surveys and plans required for the drainage of the portion of the city having the densest population, or whose natural facilities for drainage are most deficient."

The character of the surveys that would be likely to result from the authority granted by this ordinance, manifestly depends almost entirely upon the ideas of the Sewer Commissioner. At the time the

ordinance was enacted, Mr. Robert E. McMath was Sewer Commissioner, and to him belongs the credit of being the father of the ordinance and of inaugurating the surveys upon the plans under which they have been conducted. To his wise judgment and ripe experience the surveys owe their value.

Strictly speaking, three distinct surveys have been made, each one of a different character from the others, yet interlocking and combining one with the other to form one survey. In speaking of them, then, this paper naturally divides itself into three parts, the Trigonometric Survey, the Hypsometric Survey and the Topographic Survey. I will first take up the Triangulation.

TRIANGULATION.

"Geodesy, in practice, may be described as a system of the most exact land measurements, extended, in the form of a triangulation, over a large area: controlled, in its relation to the meridian, by astronomical azimuths; computed by formulæ based on the dimensions of the spheroid; and placed in its true position on the surface of the earth by astronomical latitudes and differences of longitude from an established meridian."

Systems of triangulation are usually only one triangle in width but many triangles in length. They follow the irregular coast lines of continents, the shores of inland seas and lakes, the courses of the most important rivers, and sometimes run over land for many miles to connect with other chains of triangulation, but it is a rare thing to find a system of triangulation spread out like a blanket, over any considerable area. That this will finally be done over all the land of the earth, as it is conquered by man, is inevitable.

In this country the trigonometric surveys, made and continued year after year, along our sea coasts, lakes and rivers, by the general government, have left many points and lines in their wake that are accessible as places of beginning for the more detailed surveys required by cities and towns.

The latitudes and longitudes of the triangulation stations in these systems, and the azimuths and lengths of the lines joining them have all been very carefully determined.

Owing to the triangulation of the Mississippi River from the mouth of the Illinois River to Cairo, made by the government in 1882, the city of St. Louis has been saved the expense of an accurate base line measurement, and also the astronomical determination of azimuth, latitude and difference of longitude. There are three government triangulation stations, and two triangle sides lying wholly within the limits of St. Louis.

One of the stations is the tip of the dome of the Insane Asylum,

another is a point on top of the old Stand Pipe. The length of the line between these points is 9606.164 meters, (50 meters less than six miles) and this was taken as the base line for the city triangulation. Its azimuth is 39° 45′ 01.″92 and the latitude and longitude of △ Standpipe are 38° 40′ 13.″59 and 90° 12′ 31.″51 respectively.

These values are taken from the annual report of the Mississippi River Commission for 1883.

In locating the points for triangulation stations for the purposes of this survey, it was desired that they be evenly distributed geographically; that only such places be chosen as are likely to be undisturbed for years to come; that all triangles formed should be properly proportioned; that each station be connected with the orignial base line by as few intervening triangles as possible; that the points should be easy of access for purposes of observation; that each triangle side be so situated as to become readily available as a base for other triangles, and finally, that the stations be so located as to be easily used in connecting old city surveys or as beginning points for new surveys.

Every one will recognize the impossibility of satisfying all of these requirements, in each case. The most difficult condition of all to fulfill, is the permanent maintenance of the triangulation monuments. Having no legal right of burial upon private property we, naturally, have to seek resting places for our monuments upon land owned by the city. The public parks, school house grounds, engine houses, police stations, hospitals, water works, reservoirs, and conduits, have all been liberally used.

After these available points are exhausted there remain the streets and alleys. After a street or alley is paved, stations can be so placed in them as to be reasonably secured for many years to come, the best street locations being between the side walk and curb line.

Many stations have to be put in before grades are established, streets paved or the ground dedicated.

It is these stations that will first fall, or be buried too deep for resurrection. Given the streets, alleys, and public reservations, it has still been impracticable to confine the location of stations to their limits. It is hard to get a rail road into a cemetery, but there is an affinity between a graveyard and a triangulation station. The cemeteries have been freely used for stations, permission having first been obtained from their superintendents, and lastly, resort was had to roofs of both public and private buildings. This was done after much hesitation.

The inconvenience of access, the fear that too frequent visits might wear out our welcome and lead to a final refusal of the premises for purposes of observation, the liability of the destruction of the geodetic point, by fire or otherwise, and the instability of the roofs them-

selves, for purposes of observation were the principal reasons of the reluctance to use the roofs.

Speaking from present knowledge and experience of those house top stations, the only objection to them that seems to have much weight is the possible refusal of the privilege of their use.

The fear of destruction of the points themselves has changed to a belief that next to the points in cemeteries and public parks, the stations on the roofs are likely to remain longer than any others in the city. The geodetic point of each station on a roof is marked by a small hole in the center of a copper harness rivet driven into the roof, local measurements being made to salient points on each roof sufficient to reproduce each point should any of them be destroyed. The difficulty of connecting street surveys with them is not very great, as where a direct connection by triangulation can not easily be made, any roof point can be readily transferred to a ground monument.

The objection which at first seemed the most serious of all, the instability of the roofs for purposes of observation, was overcome by a simple expedient in the manipulation of the instrument which is hereafter mentioned.

Four different instruments have been used upon the triangulation; Gambey transit No. 2, eight inch limb reading to five seconds; Fauth theodolite No. 417, eight inch limb reading to ten seconds; Buff & Berger transit No. 1229, eight inch limb reading to ten seconds; and Buff & Berger theodolite No. 1531, eight inch limb, reading to ten seconds.

Forty-five angles were measured with the Gambey instrument and the rest of the work about equally divided between the Fauth and Buff & Berger instruments.

To read an angle with a degree of accuracy sufficient for the purposes of a trigonometic survey, requires many measurements under good conditions, an essential one being, that the instrument during the time of observation, shall be subject to no disturbing influence whatever. To set a thedolite upon a common tripod, placed upon the top of an ordinary graveled roof, and under such conditions measure the angles of a series of triangles so accurately that the average closure per triangle shall be less than four seconds, would seem at first, and even second thought, well nigh impossible; but such has been done, and because it is believed that the uniformly good results are partly due to the simple expedient in manipulating the instrument, above mentioned, and because our experience may be of service to others wishing to do some house top triangulation, it is thought worthy an exact description.

To use the roof of buildings for triangulation stations at all, it is

necessary to adopt what is commonly known as the "repetition method" of reading angles.

This consists in setting the vertical wire upon first station with both motions clamped, reading the verniers, then unclamping upper motion, setting wire on second station by means of upper clamp and motion, unclamping lower motion, setting wire upon first station by means of lower clamp and motion, then unclamping upper motion and repeating the operations several times, then reading verniers at middle pointing on second station and reversing all the previous operations until the upper plate has been turned backward as many times as it was originally turned forward, then again reading the verniers.

It is evident that an observer on a roof cannot walk about his instrument to read the verniers or for any other purpose whatever without disturbing it too much to be even thought of in triangulation. But the programme above outlined can be readily carried out by clamping upper motion, reading verniers *before wire is set on first station*, then set wire on first station by means of *lower* motion, and continue operations in the usual way, until the required number of turnings have been made, then unclamp the lower motion and turn each vernier in position to be read without moving: having read them, again set the wire on second station by means of *lower* motion, and continue the negative turnings the proper number of times and make final readings of vernier.

This completes one "set," which usually takes about five minutes.

In this triangulation, four sets, two positive, and two negative, of five repetitions each, were taken upon each angle; this is equivalent to forty single measurements of each angle. The telescope has been "reverse" two sets and "direct" two sets and the limb advanced forty-five degrees between each set.

At the present writing all of that portion of the city between the limits of 1870 and the present city limits, has been covered by the triangulation. This area comprises about 27771.5 acres.

There are 87 triangulation stations, making one station to each 319.2 acres, or two stations to each square mile. Fifty-three of these stations are marked by one quarter inch hole drilled in top of limestone rock three feet long, upper ends squared to six by six inches and rest of stone undressed. Twenty-six are upon roofs, one is on a city limit stone, three are inaccessible steeples, and the remaining four are on the new Inlet Tower at Chain of Rocks, a granite monument in Calvary Cemetery, the old stand pipe, and a syenite obelisk near meteorological station in Forest Park. This obelisk is about one foot square at the top and eight feet long, and is bedded in concrete. Its apex marks the geodetic point of the triangulation station. Almost the last official act of the only Park Commissioner who ever belonged to this club,

Left-Hand Page. Right-Hand Page.

29 **29**

B. and B. Theod., No. 1531. August 24, 1891. John Doe, Obs. Richard Roe, Recorder.

OBJECTS.	VERNIER A.	VERNIER B.	MEAN.	DIFFERENCE.	ANGLE.	MEAN ANGLE.	REMARKS.
		At △ Paulian. Circle left.					
△ St. Cyr.	0° 02′ 00″	180° 01′ 55″	01′ 58″	—	—	—	flash.
△ Stand Pipe.	269 39 55	89 39 50	39 52	269° 37′ 54″	53° 55′ 35″	—	flash.
△ Stand Pipe.	269 39 55	89 39 50	39 52	—	—	53° 55′ 36″	clear and
△ St. Cyr.	0 01 50	180 01 45	01 48	269 38 04	53 55 37	—	steady.

<- space $1\frac{3}{4}''$ - × - - $1''$ - - × - - $1''$ - - × - - $1\frac{1}{4}''$ - - × - - $1\frac{1}{4}''$ - - × - - $1''$ - - × - - $1''$ - - × - - $1\frac{3}{4}''$ - ->

was to place this obelisk in position and engrave upon its four faces in letters of gold, its latitude, longitude, and elevation above city directrix, and above mean tide of Gulf of Mexico.

As the stone that used to be the city directrix has been destroyed, I would suggest that this obelisk be now taken as the city's standard Bench Mark. Although but twenty-six, of the eighty-seven stations, are upon roofs, fully two thirds of the angles read are from the roof stations.

With the exception of the triangles in which the three inaccessible stations occur, the three angles of each triangle have always been read. There are eighty-five triangles in which all of the angles were read. The average closure per triangle was 03″.7 seconds. In other words the angles have been measured with an average error of 01.″2 seconds per angle. With three or four exceptions, the triangles have all closed small. This, it is believed, accords with the experience of all observers whenever angles are measured by repetition.

Never having seen an explanation of this fact, the following is suggested as the explanation. The repeated unclamping, turning in azimuth and reclamping of both upper and lower motions of instrument, necessary in reading angles by this method, almost invariably throws the limb slightly out of level and when the limb is not level every measurement of a horizontal angle must be too small.

The note books used for triangulation were designed and made to order for this survey. The leaves are eight by ten inches, twenty-seven lines to a page with printed headings and spaces as shown in diagram on opposite page.

The actual notes of one combined result are given to show reduction of angle. The final value of the angle read appears but once, and at the bottom of the page in column headed "mean angle." It is the mean of the eight single results which are found in "Angle" column.

From each five turnings in a positive direction there results one determination of the angle, and from each five repetitions in a negative direction there results another value of the angle, the mean of two such results is called a combined result, one of them being called a single result. Eight single results were taken upon each angle. The "range" or the difference between the highest and lowest single results, has averaged for all the work 9.04″ seconds. Range depends more upon atmospheric conditions than anything else. When it is clear and signals are distinct, the range will be small; when reverse conditions prevail, the range will be large. Range also depends upon the instrument and its adjustment, but a discussion of it would be out of place here.

The probable error of any measurement of an angle, and the prob-

able error of the final result, depend upon the range obtained in observations.

From computations made from time to time it is known that the average probable error of a single result is 4.3 seconds and the average probable error of the final result is 1.5 seconds for the work of this survey.

Adjustment by least squares has not been applied to this triangulation for the reason that resort to the original base line has been so frequent that no triangle in the system is more than fourteen triangles distant from the original base line, and the checks obtained upon the lengths of the triangle sides have been numerous and satisfactory.

In consequence of the impracticability of doing all the triangulation before beginning the topographic survey, the triangulation had to be done in what might be termed districts, localities where it was desired to begin the topography as soon as possible.

The degree of accuracy obtained in the triangulation is best shown by checks obtained upon length of triangle sides. Twenty such checks were obtained; the lengths of the lines, the absolute differance, and the proportional difference for each one of these lines is given in the following table:

TABLE SHOWING CHECKS OBTAINED ON LENGTHS OF TRIANGLE SIDES.

No. of Check.	Length of Line in Meters.	Difference in Length in Meters.	Proportional Difference in Length.
1	3693.760	0.350	1 in 10555
2	5366.510	0.395	1 " 13586
3	2574.240	0.141	1 " 18257
4	2574.266	0.098	1 " 26268
5	8792.520	0.296	1 " 29707
6	2213.761	0.048	1 " 50287
7	3584.086	0.068	1 " 52708
8	5227.785	0.090	1 " 58086
9	5227.790	0.089	1 " 58739
10	1907.929	0.030	1 " 63598
11	5923.667	0.081	1 " 73132
12	3924.764	0.042	1 " 93447
13	1907.929	0.030	1 " 63598
14	2319.919	0.018	1 " 128884
15	2855.926	0.012	1 " 237994
16	3427.910	0.014	1 " 244851
17	2866.305	0.008	1 " 358288
18	2655.029	0.007	1 " 379290
19	2993.456	0.004	1 " 748364
20	1824.405	0.000	1 in ∞

The longest line in the system is 12803.065 meters equivalent to 7.96 miles. The shortest line is 628.600 meters. The average length

of all the triangle sides is 3104.6 meters, which lacks but 374 feet of being two miles.

In the computation of the triangle sides the following form has been used:

FORM FOR COMPUTING TRIANGLE SIDES.

Stations.	Observed Angle.	Adjusted Angle.	Log. Sines.	Log. Distances. Meters.	Distances. Meters.	Log. Distances. Feet.	Distances. Feet.
△ Silvester.	54° 41′ 41″	54° 41′ 42″	9.9117366	3.2805658	1907.944	3.7965546	6259.72
△ De Lore.	42 25 15	42 25 15	9.8290276	3.1978568	1577.091	3.7138456	5174.23
△ Haydel.	82 53 03	82 53 03	9.9966420	3.3654712	2319.910	3.8814600	7611.32
	179 59 59	180 00 00					

It is as convenient as it is old. By its use triangles can be computed at the rate of from fifteen to twenty per hour.

The geodetic latitudes, longitudes, azimuths and back azimuths, have been computed from the formulae to be found in Appendix No. 7, Coast Survey Report for 1884.

These formulae are:

(1) $-d\ L = K \cos Z \cdot B + K^2 \sin^2 Z \cdot C + h^2 D.$

(2) $d\ M = \dfrac{K \sin Z\ A^1}{\cos L^1}$

(3) $d\ Z = \dfrac{d\ M \sin \lambda}{\cos \frac{1}{2}\ d\ L}$

(4) $Z^1 = Z + 180^\circ - d\ Z,$

in which $d\ L$ = difference of latitude,

K = Distance between stations,

Z = Azimuth from 1st. station to 2nd. station,

Z^1 = Azimuth from 2nd. station to 1st. station, or back Azimuth,

L = Latitude of 1st. station,

L^1 = Latitude of 2nd. station,

M = Longitude of 1st. station,

M^1 = Longitude of 2nd. station,

λ = Latitude of point midway between 1st. and 2nd. stations,

$h = K \cos Z + B,$

and, A^1. B, C, and D are logarithmic factors, computed for Clarke's value of the spheroid. They are constant for the same latitude, but change in value with change of latitude. The Coast Survey report referred to gives, in tables, their values for each minute of latitude, from which their values for any number of seconds is easily deduced.

To facilitate computation these four formulæ have been dissected and the parts arranged upon one page in such a manner that the terms which are to be added to or substracted from each other can be entered in vertical columns as fast as computed and the final operations performed.

The formulæ as they appear after dissection, with all the terms arranged for rapid computation are given in the following form, representing one page of actual computation. (See page 11.)

With the entire formulæ previously given it is not difficult to follow the operation of actual computation.

The only change made is in using the arithmetical complement of Cos L^1 instead of Cos L^1. This is a short cut off to avoid adding K, sin Z, and A^1 and then subtracting Cos L^1 from their sum. This computation is self checking.

The geographical positions commonly called the *D M's* and *D P's*, are next computed. These are the co-ordinates of longitude and latitude respectively, and are the values used in plotting the stations upon the maps. On this survey both plus and minus co-ordinates of latitude and longitude have been computed for each triangulation station; besides being a convenience they furnish a check upon the computation of the *D M's* and *D P's*. During the first-half of the field work much delay was caused by smoke. Round targets eight feet long, one inch and a quarter in diameter, each alternate foot painted black and white, had been used. These targets were accurately plumbed and held in position by small tripods made for this purpose. The targets made such nice vaulting poles for the boys that it became necessary to have them watched while observations were in progress. The smoke finally became so great and constant a nuisance that the target tripods were all rigged out with heliotropes, and instead of watching targets, each man flashed a steady stream of sunlight to the observer. This worked so well that no pole targets were subsequently used. One leg of each tripod was fitted with a *V* shaped board painted white to be used as a target when there was no sun. This leg was always plumbed on line to observer and a strip of black cloth fastened behind it for a background. The upper portion of the rest of the tripod was painted black for the same purpose.

These tripods, complete, cost two dollars each; five of them were used and it is certainly within the limits of truth to say, that each one of them saved a hundred dollars to the city. The essential features of one of these tripods, with heliotrope attached are shown in Figure 1.

The mirror *M* is mounted on a *U* shaped support *Y* revolving on a vertical axis which is plumbed over geodetic point, the plumb line being attached to its base.

The mirror also revolves about a horizontal axis P. At the end of

Form used in computing Geodetic Latitude, Longitude, Azimuths and Back Azimuths for secondary Triangulation.

Z	△ Christian Bro. College to Insane Asylum.	11° 33′ 11.085″
✓	△ Stand Pipe and Insane Asylum.	109 03 21.
Z	△ Christian Bro. College to Stand Pipe.	262 29 50.085
$d\,Z$	....	+ 02 02.914
180°	....	180° .. ..
Z^1	△ Stand Pipe to Christian Bro. College.	82 31 52.999

L	38° 39′ 53.323″	Christ'n Bro. College.	M	90° 15′ 48.235″
$d\,L$	+ .. 20.267	4796.84	$d\,M$	— 03 16.725
L^1	38 40 13.590	Stand Pipe.	M^1	90 12 31.510

		K	3.6809556	K^2	7.36191			
λ = 38° 40′ 03.47″		Cos Z	9.1158562	Sin² Z	9.99253	h^2	2.615
		B	8.5109528	C	1.30782	D	2.382
1st. term.	20.313	h	1.3077646		8.66226		4.997
2d. & 3d. terms.	.046		—20.313″		0.046″		0.000″
— $d\,L$ —	20.267						

K	3.6809556		
Sin Z	9.9962658		
A^1	8.5091520	$d\,M$	2.2938599
Ar. Comp. Cos L^1	0.1074865	Sin λ	9.7957421
	2.2938599		2.0896020
$d\,M$	— 196.725″	— $d\,Z$	— 122.914

the arm C is the screen S which is of pasteboard and furnished with slides having circular apertures of varying dimensions. A, is an eye screw attached to clamp to regulate force required to turn mirror upon its vertical axis. TT is the V shaped board inserted in one leg of tripod and used as a target whenever sun is obscured by clouds. In practice it is, of course, always plumbed on line to observer and not at right angles to mirror arm as shown in Figure. There are several

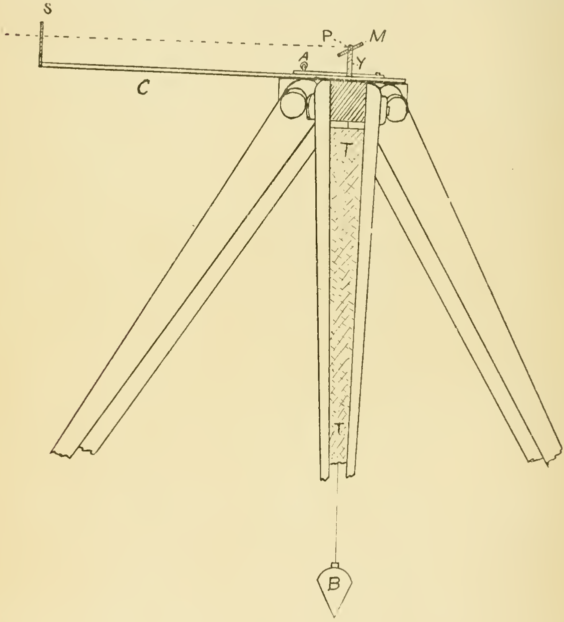
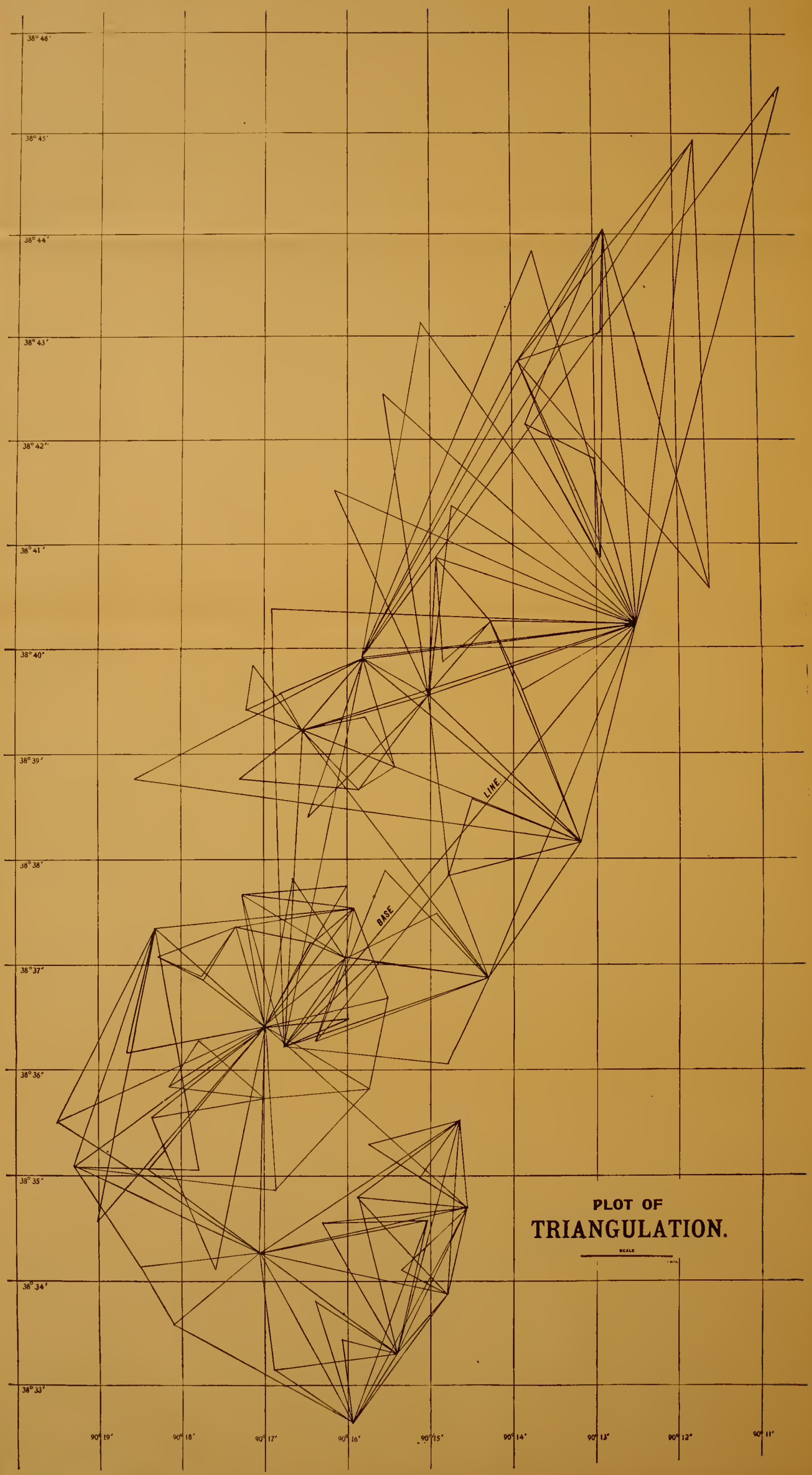


FIG. 1.

other little details connected with this apparatus which are not mentioned. To adjust it so as to send a ray of light over any right line is a simple matter.

First plumb the center of the mirror over geodetic point with its arm approximately on line over which flash is to be sent. Turn mirror to a horizontal position, sight over its center to mark and bring aperture in screen in line with center of mirror and mark. This can be done approximately in the above way, but to direct line of sight exact-



PLOT OF
TRIANGULATION.
SCALE
BASE
LINE.
38° 46′
38° 45′
38° 44′
38° 43′
38° 42′
38° 41′
38° 40′
38° 39′
38° 38′
38° 37′
38° 36′
38° 35′
38° 34′
38° 33′
90° 19′
90° 18′
90° 17′
90° 16′
90° 15′
90° 14′
90° 13′
90° 12′
90° 11′

ly it is best to turn your back to mark and looking in the mirror, move the screen into such a position that you see the mark and the center of the aperture both in the exact center of the mirror. The three points are now in a straight line and it is only necessary to turn the mirror into a position that will throw the sun's image through the aperture. Keep it in this position by turning it upon both axes from time to time and a steady light will be maintained. A mirror one inch in diameter and a quarter inch hole in screen were used upon this survey. The men operating them were taught the Morse telegraphic alphabet and directed in their work by telegraph, it being only necessary to intercept and release the light at the proper intervals to produce the dots and dashes obtained over the wires by breaking the current.

The average closure of all the triangles when targets were used was 4.6 seconds; the average closure when flashes were used was 2.7 seconds; the average closure of all triangles being 3.7 seconds.

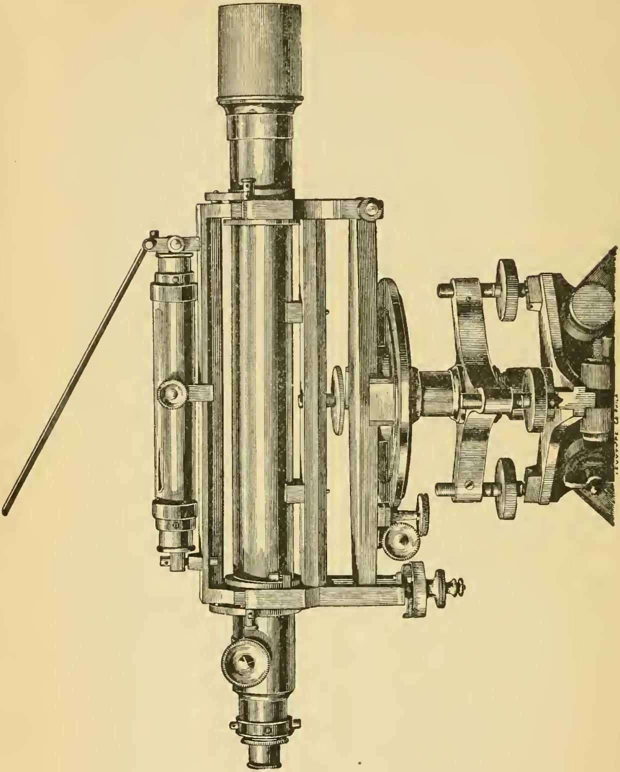
PRECISE LEVELS.

A few months ago, *Engineering News* contained an article describing as new and unknown to the editor, a leveling rod used in Switzerland, and recommended its use in the United States. The fact that such rods have been in general use upon our most exact Hypsometric surveys for over twenty years, shows how very little is known, even among engineers, of what is called Precise Leveling. It is easy to ask; "What is Precise Leveling," and just as easy to answer, but to convey any real knowledge of the subject in the few minutes at my disposal this evening wiil not be attempted.

I think a paper has been read before this club upon this subject, and another is promised soon, by a member more competent than myself to discuss Precise Leveling.

The methods we have followed for the city work are identical with those most commonly used by the U. S. Asst. Engineers under the War Department, but differ somewhat from those of the Coast Survey.

Several members of the club having expressed a desire to see a Precise Level, I have brought over the instrument used upon this survey, also one of the rods, foot plates etc., and will briefly describe them. The Precise Level was made by Fauth & Co., Washington D. C., the rods by Kern of Switzerland. The cost of the outfit delivered in St. Louis was about $550.00. The level has given quite as good



LEVEL OF PRECISION.

Level of Precision for the most exact work can also be used as a gradientor, the micrometer-screw for raising or depressing the telescope being made with the utmost exactness, and provided with a graduated head. The telescope has an aperture of 1½ inches, 16 inches focus, with two astronomical eye-pieces, magnifying 40 and 60 times, respectively. The striding-level is chambered, and one division equals 3 seconds of arc. The horizontal circle, of five inches diameter, divided on silver, reads to 30 seconds; the center is of steel: clamp and spring tangent motion.

results as the Kern Levels.* A Precise Level party consists of one observer, one recorder, two rodmen, one bench-cutter and one umbrella man. Two large wagon umbrellas are always used, one protects from the sun, and the other from the wind. On very windy days Precise Leveling can not be satisfactorily done. Seven hundred and forty-three (743) Precise Benches have been established, an average of twelve (12) per square mile.

They are distributed over the entire city. It is needless to say that all of these Benches were not made for the purposes of the Sewer Department, but are intended for use by all Departments of the municipal government, and also for City Surveyors.

Most of the Benches are upon the stone or iron sills of buildings; some are on stone bridges, culverts, city limits and triangulation station stones; a few are spikes in trees and some are copper bolts leaded into tile slabs buried below frost-line and connected with surface by tile pipes. A minute description of the location of each one of the benches, with their elevations, is printed each year in the report of the Sewer Commissioner.

The total distance of Precise Levels completed in duplicate is 240 miles. All stretches have been duplicated in opposite directions. If the difference of closure was greater than 0.0208 feet into the square root of the distance in miles, the stretch was run over twice more in the same manner until a closure was obtained coming inside this limit. In all, thirty-one (31) stretches have been outside of the limit and were re-run.

The average difference of closure per mile has been 0.009 feet, the average difference of closure per stretch has been 0.003 feet. The average length of stretches has been 484 meters. The probable error in determination of a single mile of work is 0.001 feet.

A general idea of the numerical values of the differences in elevation obtained by the first and second leveling between benches may be obtained from the following table which shows the total difference in elevation at end of each mile throughout a course of fifty-six miles. When elevation determined by first run is higher than elevation determined by second run the sign preceding difference in elevation is plus and changes sign when the reverse is true.

The average distance between benches in the fifty-six miles is 394 metres; the average number of settings of instrument between benches is 4.7; the average difference between forward and back runs is 0.7 millimeters; the total number of forward and back runs (each) in fifty-six miles is 229.

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*Here a verbal description was given of the Precise Level and Rod including their practical operation and manipulation.

Distance in Miles from Starting Point.	Differences in Elevation between forward and back Runs. (Millimeters.)	Distance in Miles from Starting Point.	Differences in Elevation between forward and back Runs. (Millimeters.)	Distance in Miles from Starting Point.	Differences in Elevation between forward and back Runs. (Millimeters.)
0.	0.0	20	— 0.1	40	+ 5.0
1	— 0.1	21	— 0.1	41	+ 3.5
2	+ 2.0	22	— 1.5	42	+ 1.1
3	+ 1.0	23	— 3.4	43	+ 0.9
4	+ 4.3	24	— 4.2	44	+ 1.0
5	+ 4.6	25	— 7.3	45	— 0.9
6	+ 5.8	26	— 5.4	46	+ 4.1
7	+ 8.1	27	— 6.2	47	+ 4.1
7.7	+10.4	28	— 8.4	48	+ 5.8
8	+10.2	29	—10.5	49	+ 9.4
9	+ 6.5	30	— 8.9	50	+ 9.9
10	+ 6.9	31	— 9.6	51	+10.2
11	+ 6.4	32	— 7.5	52	+ 8.1
12	+ 4.9	33	— 7.1	53	+ 8.0
13	+ 5.7	34	— 3.7	54	+10.3
14	+ 5.5	35	+ 0.6	54.3	+10.5
15	+ 3.9	36	— 1.0	55	+ 8.4
16	+ 3.6	37	+ 1.7	56	+ 7.2
17	+ 3.0	37.5	0.0		
18	+ 3.1	38	— 0.6	56	=P. B. M. No. 799.
19	+ 1.8	39	+ 2.7		

TOPOGRAPHY.

The coordinates of the topographic survey are based upon the geodetic latitudes, longitudes, and azimuths of the triangulation. Its vertical heights are derived from the Precise Level benches.

Starting from the several triangulation stations, lines have been run with theodolite and stadia over all that portion of the city lying between the present city limits and those of 1870, a total area of about twenty eight thousand acres.

The city directrix was taken as zero, and contours in multiples of three feet above and below this datum have been mapped. Buildings, with few exceptions have not been located. Such street corners as could be readily found were connected. Fences marking street lines have generally been taken. A complete survey of the streets has not been attempted. The streets have been developed upon the maps by means of the records to be found in the Street Department and in the office of the President of the Board of Public Improvements, first using the stadia connections obtained with the street corners. Here and there a street corner was connected by triangulation.

The note books used were made to order for the survey. The headings are printed and are shown on following page.

Left-Hand Page. | Right-Hand Page.

50								50
OBJECTS	DIST. METERS.	VERNIER A.	VERNIER B.	VERTICAL ANGLE.	DIFF. OF ELEVATION.	ELEV-ATION.	REMARKS.	
<- 1¾" ->	<-½"->	<- 1" ->	<- 1" ->	<- 1½" ->	<- 1¼" ->	<½">	<- 4" ->	

They are probably as convenient for topography as any note books in use.

All of the topographic work has been done upon true azimuth. That is, every horizontal angle read to locate a point has been the angle that the line from the instrument to the point makes with the true meridian.

This method has many advantages over the common way of setting Ver. *A* at zero upon back stake. It takes no more time in practice and ought always to be adopted, but will not be adopted until teachers of surveying become better acquainted with modern methods than most of them are at present.

For the want of a better name this method has been called, "The method of carrying azimuth." In practice the field operation is as follows. The theodolite is first set over a triangulation station, or some point from which a true azimuth has been previously determined; vernier *A* is set to read this previously determined azimuth and both motions clamped with the telescope directed upon this line. If zero degrees is taken to be South, which is commonly the case, the telescope will always point South when Ver. *A* reads zero degrees, and every reading of Ver. *A* will be the angle made by the line from the point to the instrument, with the true meridian. Always to orient the instrument in this position it is only necessary to make Ver. *A* read on the back sight the same as Ver. *B* did on the fore sight. Since the zeros of the verniers are not always exactly 180° apart, it is best to take only the degrees form Ver. *B* and the minutes and seconds from Ver. *A*.

The topographic field party consists of six men, observer, recorder, three stadia men, and one general utility man.

The distances to and from the work have been so great that not more than six hours per day of actual field work has been averaged. Counting all the days upon which any notes at all have been taken, as full days, it appears that there are four hundred and seventy one (471) days upon which topographic work was done. The distances between stadia stations and the vertical angles have always been read in both directions. When a Precise Level Bench was tapped for elevation the vertical angle was read twice, once with telescope direct, and once reversed and mean value taken.

Considerable has been written about the proper way of determining the one hundred meter wire intervals for stadia boards. Before determining the interval for the boards used upon this survey an estimate was made of the *probable* average distance between stadia stakes.

This estimated distance was two hundred (200) meters, and after putting the stadia wires in the telescope the intervals subtended by them on a base line of that length was determined, the *center* of instrument being placed over one end of the base. The mean of ten results

was taken. Half of this distance was used for the one hundred (100) meter intervals and the boards subdivided as shown in Fig. 5. The 100 meter marks were painted red and one of them was placed in the *middle* of each board. For ready recognition of proper height of instrument for reading vertical angles, a small bar was placed across each 250 meter mark.

An important fact learned on this survey, relating to the graduating of stadia boards is *never to determine the wire interval in the morning or after four o'clock in the afternoon.* These are the very times most likely to be selected for this work, for we all know that the air early in the morning and just at night is steadier and freer from radiation, or boiling, as it is termed, than it is at any other portion of the day.

It is also well known that refraction is much greater before nine o'clock a. m. and after four o'clock p. m., than it is between those hours, but I for one, never supposed that it was great enough to vitiate the results of a determination of wire interval over a base as short as 200 meters, until March 2nd. 1892.

On that date the following observations were made for determining wire interval for *B.* and *B.* Theodolite No. 1531, over a 200 meter

TABLE I.

TIME P. M. 3-2-1892.	READING OF UPPER WIRE.	TIME P. M. 3-2-1892.	READING OF UPPER WIRE.
4:42	6.02	4:51	6.03
	6.02		6.04
	6.02		6.03
	6.02		6.06
	6.02		6.09
4:46	6.02	4:56	6.09
	6.02		6.11
	6.04		6.12
	6.04		6.11
	6.03		6.13
4:50	6.04	5:00	6.14
			6.13
			6.15
			6.16
			6.18
			6.19
		5:05	6.20

TABLE II.

TIME A. M. 3-3-1892.	READING OF UPPER WIRE.
11:40	6.02
	6.01
	6.01
	6.01
11:44	6.01
	6.02
	6.02
	6.01
	6.02
11:48	6.03

base line measured on a stone curb in Portland Place. The notes are copied from a note book of this survey. A Philadelphia leveling rod, having an extra target, was used; the second target being moved into

position each time by signals from observer and rod kept vertical by extra man with plumb line. Lower target and wire being set at 2.0 feet mark of rod. The readings given are of upper wire.

The above observations were suspended at 5:05 P. M. because the great refraction shown was noticed and the next day between 11:30 and noon the observations given in table 2 were made over the same base in exactly the same manner.

Refraction as great as shown in table 1 at the same time of day, is probably not frequent, still it is liable to occur and if these notes do not prove the statement previously made, they certainly warn us that wire intervals should be determined during the middle of the day. They also indicate, and we think prove, that there are times when distances read by stadia are not to be depended upon. For this reason too, we should avoid setting stadia *stations* at these times.

Another point, which some will not fail to apply, is, that they furnish a first-class reason for beginning work late and quitting early.

Those who have used the stadia a good deal, wonder why it is not in more general use; upon the other hand, those who have never used it, wonder why it is ever used at all. They have seen pictures of stadia boards, perhaps may have once seen a real live stadiaman dodging about a field in a, to them, drunken sort of a way; they have probably heard something about its use and had sufficient interest or curiosity to read a little of the theory, but this class always comes to a full halt when they find that in all stadia readings, there is a constant error due to focal length. Their doubts now crystalize into convictions, and they positively *know*, that because of this constant error, all stadia work is of no account.

The more experience I have with stadia work the stronger becomes my belief, that *if* this error of focal length (which so many believe, and some know, renders all stadia work worthless,) were greater, say about twice as great, as it really is, and then no correction applied for it, all work done with the stadia would be nearer right than it is when correction for this "ghostly" error has been made.

This I know is heresy, heresy of the most pronounced kind. But a little heresy is good medicine, and oils rather than retards the wheels of progress and science.

Possibly no one here to-night believes what I say about the focal length error, yet the statement is not made care lessly, or recklessly, or without reasons for its support. The

Fig. 5.

principal reasons are, 1st. the known fact that if any considerable number of stadia courses, not in a loop, are taken, and their coordinates computed, it will be found that the distances have invariably been read too great. If the correction for focal length had been applied they would be still greater. 2nd. The errors due to refraction (and we have shown that they may be very great) *nearly* always cause distances to be read too long. 3rd. When the stadia boards are not held vertical, distances are read too great. Errors due to one or all of these causes occur *all* the time and they are all in the same direction. It is my belief that their average aggregate error is greater than the known constant error due to focal length, hence the opinion expressed, that if this error were about twice as great as it really is *and then neglected,* better results would be obtained.

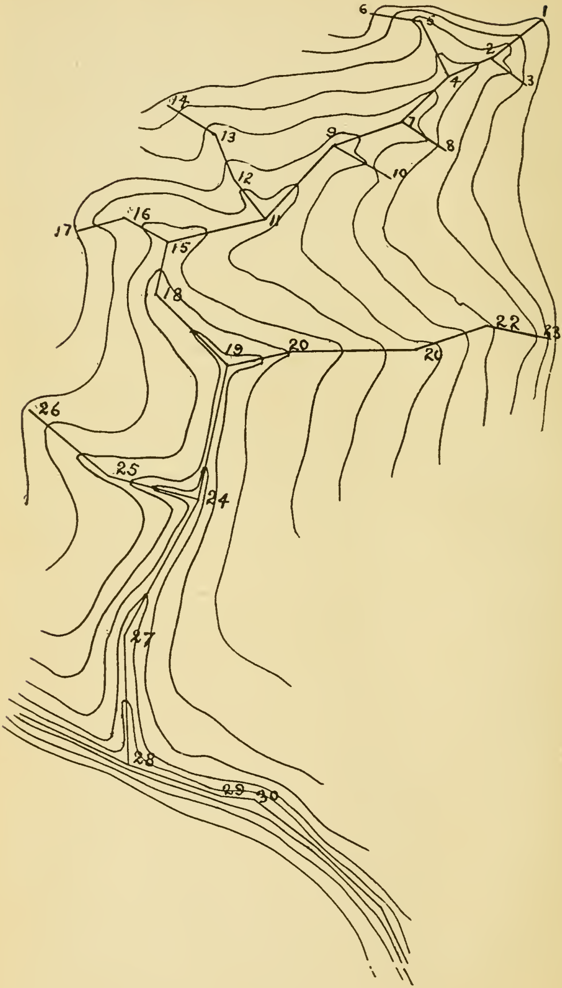
After saying this it is needless to add that in this survey no correction for focal length has been made. Strong proof in support of this opinion and of a practical kind, will be given elsewhere in this paper.

The topographic notes were taken almost entirely without sketches. This saves about one quarter of the time of the entire field party. Probably all of us were taught to make more or less elaborate field sketches. Teachers of surveying, are still telling their boys to "sketch everything an inch high and a minute old." It seems to me that the time an experienced topographical engineer spends in sketching is almost wasted. The power to devise a simple system of taking topographic field notes without sketches lies within the capabilities of every trained surveyor.

Such a system is never complete; it is always growing and will spread out in any direction to meet the varying conditions of any locality. A practical system cannot be devised at the desk, it must be built up from day to day as the needs of actual field practice demand. Here "Necessity is the mother of invention."

Briefly to illustrate the fundamental principles of such a method your attention is called to the following diagram, the points located being numbered. See pages 22 and 23.

In a similar manner all the topographical features can be taken and entered in the notes with two or three words so exactly that no mistake can be made in plotting. No time is lost in sketching and when the notes are plotted, instead of a sketch, which is always inaccurate, you have before you a correct map in every detail, about which there is no guess work whatever. Probably as severe a test upon such a system, as is ever met with, is the taking correctly of the various tracks, switches, turnouts, crossovers, headblocks, etc., found in a rail road yard. The system comes out successfully from such encounters, every time. In the office, as soon as all the points which determine the drain



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In the "Objects" column of the note book these points would be designated as follows:

1. Head of thalweg.	16. Gully 4.
2. Gully 1 joins thalweg.	17. Head of gully 4.
3. Head of Gully 1.	18. Thalweg.
4. Drain 1 joins thalweg.	19. Drain 3 joins thalweg.
5. Drain 1.	20. Drain 3.
6. Head of drain 1.	21. Drain 3.
7. Gully 2 joins thalweg.	22. Drain 3.
8. Head of gully 2.	23. Head of Drain 3.
9. Gully 3 joins thalweg.	24. Draw 1 joins thalweg.
10. Head of gully 3.	25. Draw 1.
11. Drain 2 joins thalweg.	26. Head of Draw 1.
12. Drain 2.	27. Thalweg.
13. Drain 2.	28. Thalweg joins creek.
14. Head of Drain 2.	29. Creek.
15. Gully 4 joins thalweg.	30. Creek.

age courses are plotted, their consecutive points are joined by right lines in pencil. After this is done it is almost impossible to make a mistake in drawing the contours.

The topography has been plotted on mounted antiquarian sheets 28 × 50 inches inside of border lines, scale 200 feet to the inch; each map thus covers almost exactly two square miles.

Lines representing each twenty seconds of latitude and longitude are first projected on these naps. Then the triangulation and stadia stations are projected by rectangular coordinates, and the points of elevation by polar coordinates. The tables used for the projection of these maps are to be found in Appendix No. 6. Coast Survey Report for 1884. They are based upon a polyconic development of Clarke's value of the Spheroid, and are computed from the equator to the pole.

Col. Clarke, Royal Engineer of the British Ordnance Survey Office first published these tables in 1886; they have almost if not entirely superseded Bessel's.

As the ratio of our yard to the meter depends upon the value of the meter derived from the computations of Col. Clarke, it may be well to give a few figures in this connection. Bessel's value for the Equatorial semi- Axis is, $a = 6{,}377{,}397.2$ meters.

Polar semi Axis, $b = 6{,}356{,}079.0$ meters, their ratio being $a : b :: 299.152 : 298.153$.

Clarke's values are $a = 6{,}378{,}206.4$ meters, $b = 6{,}356{,}583.8$ meters: ratio $a : b :: 294.98 : 293.98$.

Clarke's Equatorial Semi- Axis is8 09.2 meters greater than Bessel's and his Polar Semi- Axis is 504.8 meters greater than Bessel's.

The ratio of our yard to the meter as given by Clarke is, 1 meter = 1.093623 yards = 39.370432 inches.

Col. Clarke had for his computations all the data used by Bessel and

much more of later date, mostly from the geodetic surveys made in India by the British government. Up to this date the location and elevation of 111304 points have been determined by stadia, an average of four points per acre. Two-thirds of these points were plotted with a paper protractor thirteen inches in diameter, graduated to quarter degrees, four hundred and fifty points being an average days work.

Now a metal protractor, especially devised for plotting by polar coordinates and constructed for this survey, is used. An average days work with this protractor is 750 points. It is easier to use and much more accurate than a paper protractor

Its construction is shown in some detail in Figure 6.

All stadia distances have been read in meters. This was done because the best and most complete tables for finding the difference of elevation between two points when distance and vertical angle are known, are computed for distances read in meters, and differences of elevation in feet. These tables are published by the U. S., Government and widely known as "Ockerson's Tables." They give the difference in elevation in feet to hundredths of a foot for each multiple of ten meters up to six hundred (600), and for vertical angles up to ten degrees, the excess over the multiple being found by side column of proportional parts. About two thirds of the stadia elevations were reduced with these tables; the rest were computed with a slide rule, especially adapted for this work. It has been found in practice to be about three times as rapid as the tables and almost as accurate. It will give about 25 per cent, of the differences in elevation met with in stadia work, correctly to the nearest thousandth of a foot, about 50 per cent. to the nearest hundredth of a foot, and all differences to the nearest tenth of a foot. It also saves much mental labor of a grinding nature and can be used by any person of ordinary intelligence after a few minutes instruction.

The construction of this scale is shown in Figure 7 the labor of

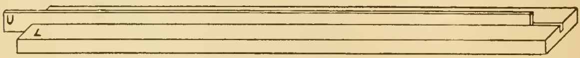


FIG. 7.

drawing is too great to admit of an attempt to show the divisions on the scales. (The slide rule itself was shown to the club.)

The upper scale U is a logarithmic scale repeated twice, the logarithms being affected by a constant coefficient whose value in this case was taken great enough to give correctly to the nearest tenth of a foot all the differences of elevation commonly met with in topographic surveying with stadia. The lower scale L, is the arc scale and is graduated up to twenty degrees to give differences of elevation in

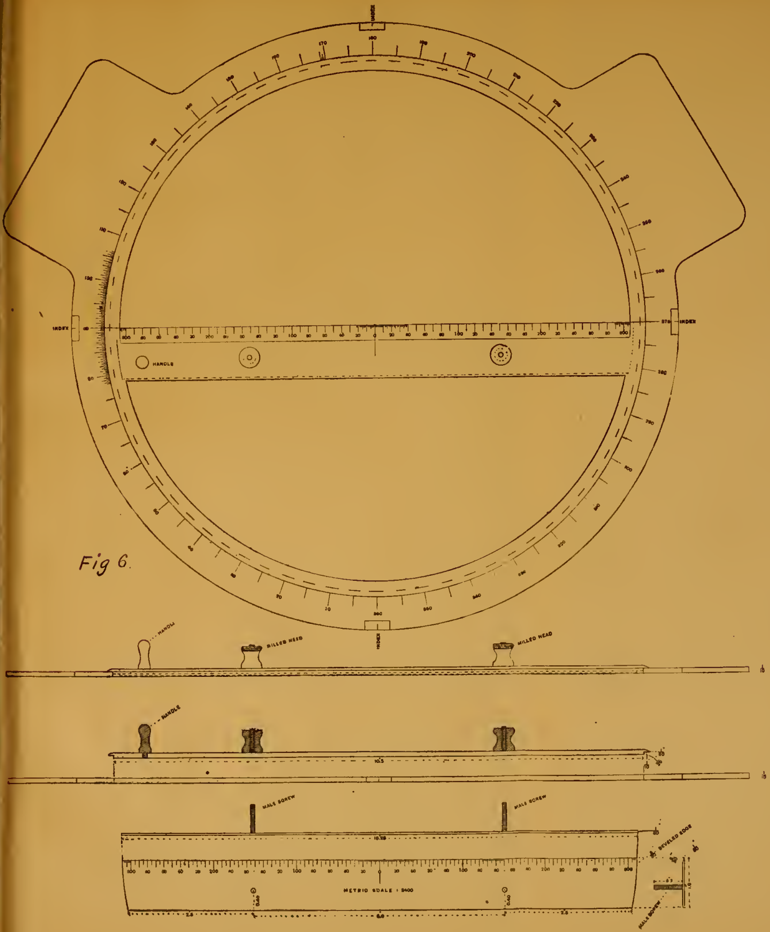

INDEX
INDEX
INDEX
INDEX
HANDLE
MILLED HEAD
MILLED HEAD
HANDLE
MALE SCREW
MALE SCREW
BEVELED EDGE
METRIC SCALE 1:2400
MALE SCREW

Fig 6.

feet for distances read in meters. Fractions of meters in distance and fractions of minutes in arc are computed by the scale just as quickly and easily as whole numbers.

In using the scale the graduation mark on the logarithmic scale representing the distance read in meters is brought coincident with the zero mark on the arc scale, and the difference in vertical height read from the upper scale at the point coincident with required vertical angle on lower scale.

The stadia boards used were twelve (12) feet long and five inches wide. The one hundred meter intervals were 2. 61 feet apart. The figures are as shown in figure 5. It will be noticed that the ten meter mark at the ends of the boards are of slightly different pattern than the others; this is to identify top of board with certainty, which is essential whenever vertical angles can not be read to height of instrument. The bars across the 250 meter marks serve a similar purpose. Small matters of detail, but by their use work is done faster and better.

As to the best figures to use all experienced observers will, I think, agree with Mr. Ockerson who in the preface to his tables says: "The correct principle to follow out is to keep the colors as much together as possible, for, when the air is unsteady the figures will run together to such an extent that it will be impossible to distinguish them. Large figures with points to indicate the smaller divisions, are better than small detached figures."

The figures given in Fig. 5 are believed to be as good as any in use. The space from center to center of each figure corresponds to a distance of ten meters; the vertical length of each figure represents a distance of eight meters. This decimal division of the stadia should always be maintained whatever unit of measurement is used. It will be noticed that the points of each figure represent a distance of two meters, that all distances represented by points are even, while all distances between adjacent points are odd numbers. If the theory of probabilities is correct, and we believe it is, it follows that in the course of a topograhical survey as many points will be located at *even* distances from the instrument, as there are located at *odd* distances, and the greater the number of points located the nearer will be the ratio of the odd and even points to the whole number of points located.

If in practice this is tested and found not to be true, there must be some reason for it, either in the theory, the observers, or elsewhere. It occurred to the writer that owing to all the even distances being represented by points and all the odd distances by estimation of space between the points, in practice there would be an inclination to take the well defined point instead of the unindicated space, especially as in this case estimate has to be made of the vertical distance of

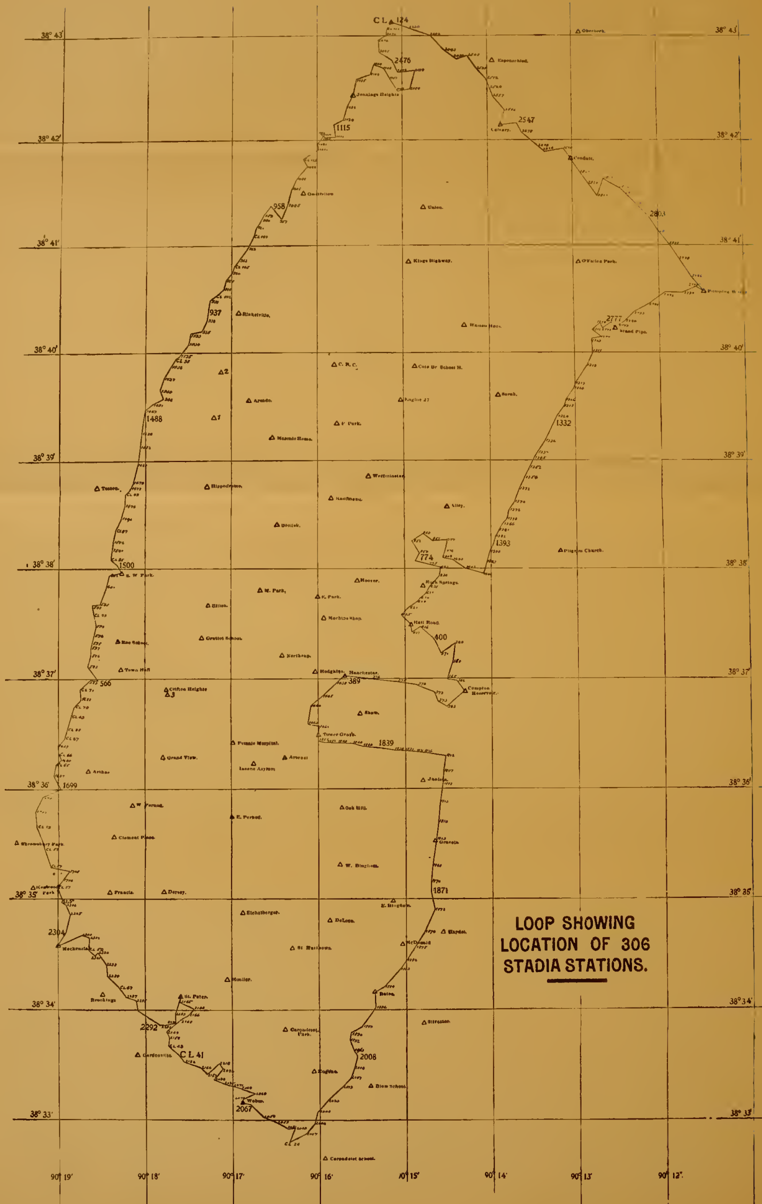
the point of intersection of a horizontal and oblique line from the ends of the oblique line. To test this supposition all the stadia distances read and recorded in twenty-three note books have been counted, in all 49,140 readings; of these 27,962 were of even distances and 21,178 were of odd distances, making 6,784 more even than odd distances. In other words 43.1 per cent. of all the distances read were odd and 56.9 per cent. were even. The notes of four different observers were taken and the individual results given in the following table:

TABLE III.

No. of Note Book.	Observ'r.	No. of Even Dist.	No. of Odd Dist.	Per Cent. of Odd.	Total No. Even.	Total No. Odd.	Total P'r Cent. Odd.
39	1	1262	773	38.0			
3	1	1163	721	38.3			
18	1	1382	842	37.8	7928	5031	38.82
43	1	1403	936	40.0			
2	1	1400	911	39.4			
17	1	1318	848	39.1			
24	2	1465	787	34.9			
25	2	1261	714	36.2			
22	2	1203	929	43.6	6449	3894	37.60
23	2	1500	793	34.5			
21	2	1020	671	39.7			
5	3	935	790	45.6			
6	3	918	768	45.6	2965	2528	46.02
7	3	1112	970	46.6			
38	4	1118	1138	50.5			
37	4	1071	1129	51.3			
36	4	1127	1243	52.5			
33	4	1096	1090	50.0			
28	4	1281	1052	45.1	10620	9725	47.80
27	4	1333	962	41.9			
26	4	1411	958	40.4			
29	4	1051	1061	50.2			
30	4	1132	1092	49.1			
				Total.	27962	21178	43.1

If the notes of observer No. 4 had not been examined, I should feel pretty certain that the large excess of even readings was due to the *points* upon the figures of the stadia boards. The notes of the fourth observer indicate that it *may* be purely a matter of personal equation.

To test still further the matter, and settle the question if possible, I have had a set of boards graduated and painted with figures without points. These figures are shown in Fig. 8.



LOOP SHOWING LOCATION OF 306 STADIA STATIONS.

I expected to be able to give the results of readings made upon these new boards but other work has thus far prevented their use and it will be some months before results of their use can be known. Taking the risk of proving to be a false prophet, the prediction is ventured

FIG. 8.

that the number of even and odd readings on the new boards will be practically the same. If this proves to be the case it will follow *that figures having points should not be used.*

The rectangular coordinates of all stadia stations have been computed. The axis of reference being the parallel and meridian passing through the nearest twenty seconds of latitude and longitude respectively.

A large Record Book especially designed for this computation was made. The headings of pages in this book are printed and are as follows. See pages 28 and 29.

The computations were first made on separate paper and checked. Afterwards copied into Record Book in pencil, then carefully compared with original computation and finally the figures in pencil were inked.

In computing the coordinates of stadia stations, lines joining two triangulation stations were first selected. After checking computation the error was distributed equally among the stations in the line. After the stadia lines joining triangulation stations were adjusted the cross lines were computed and adjusted in the same manner, care being taken to take as direct lines as possible between stations whose coordinates had been previously computed and adjusted.

In the Record Book are the results of the computations of hundreds of such lines, showing the exact checks of each and consequently the actual accuracy of the work itself. It would be very easy to extract from the Record Book any number of them and read off the checks, as the entire computation and adjustment of each line is on record. This course however would lead some to think that only such results as were first class were selected, and that the poor ones were suppressed. To prevent any such opinions being formed, I decided to compute separately the coordinates of the outside line of stadia stations encircling the city. This computation has accordingly been made; the results of it are thought by the writer to be the most valuable part of this paper. This line starts from triangulation station on City Limit Stone No. 124 at intersection of Mead St. and McLaren avenue and returns to same

Station.	Dist. Meters.	Azimuth.	Log. Sine.	Log. Cosine.	Diff. Long.
△ Rock Springs.	149.8	340° 08′ 10″	9.5312066	9.9733599	—50.90
□ 617			2.1755118	2.1755118	
			1.7067184	2.1488717	
□ 617	209.75	45° 59′ 10″	9.8568324	9.8418803	+150.85
□ 628			2.3217020	2.3217020	
			2.1785344	2.1635823	

point. The total length of the line is 64970.4 meters, equal to 40.4 miles. In the line there are 306 stadia stations, giving an average distance of 211 meters between stations.

Values derived from the *initial* latitude, longitude, azimuth and elevation, of triangulation station City Limit 124 (the starting point) were alone used and carried, by stadia through each of the 306 courses in the line. The idea of this plan is, of course, to compare the new latitudes, longitudes, elevations, and azimuths of each station in the line with the original values previously determined. If such a computation and comparison has ever been made before it is unknown to the writer. It is believed to be extensive enough (over forty miles) to show accurately the limits of precision in stadia work that can be safely counted upon in practice.

As the computation covers twenty-four pages, time will not permit me to show you the checks upon each one of the stations, but I will give you a table showing all the checks upon the stations at the bottom of each page of the computation and plot the curves representing the *differences* in latitude, longitude, elevation and azimuth found at each of these stations. The computation was checked three times.

The table also shows the distance in meters and in miles each station is from the starting point, and the distance in miles between each station and the preceding one.

Looking at the column giving difference in azimuth it will be seen the greatest is 0° 12′ 35″ at station 937, 34.9 miles from starting point and that the closing error for the entire loop was 0° 08′ 20″. Note too, that the direction of the error in azimuth was always the same from first to last. To digress a moment from the table and speak of azimuth errors.

From an actual count of all the azimuth checks contained in 1000 pages of notes, which is nearly one-fifth of all, I have found that 61.2% are less than one minute, 15.3% were between one and two minutes, 9.4% between two and three minutes, 9.4% between three and four

Diff. Lat.	Adjusted Diff. Long.	Adjusted Diff. Lat.	Longitude.	Latitude.	Elevation.	Remarks.
—140.89	—50.91	—140.55	—781.62	+339.14	126.32 55.03	90°15′20″ 38°37′40″
—145.74	+150.81	—145.38	—832.53	+198.59	65.47	" "

minutes and 4.7 % between four minutes and four and one-half minutes. No errors greater than this were found. Referring to the table again. The next column shows the differences of elevation. Here too the errors are all in one direction, the greatest being at station 2304 and amounting to 1.37 feet, 27 miles from starting point. The error of closure we see is

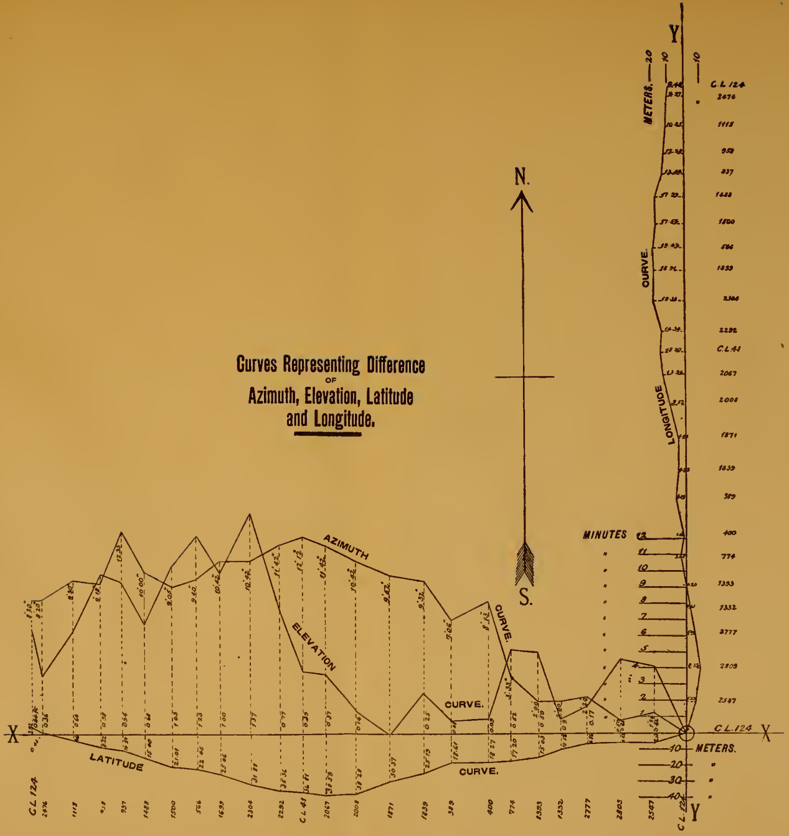
Page.	Station.	Difference in Azimuth.	Difference in Elevation in Feet.	Difference in Latitude. Meters.	Difference in Longitude. Meters.	Dist. in Meters from Starting Point.	Dist. in Miles from Starting Point.	Dist. bet. Consecutive Sta.	Diff. of Lat. & Long. in Proportion to Dist. from Starting Point.
1	2547	+0°01′ 20″	+0.42	— 6.35	— 5.39	3218	2.0		1:387
2	2803	+ 00 50	+0.46	— 6.62	— 8.32	6576	4.1	2.1	1:619
3	2777	+ 02 20	+0.17	— 6.86	— 5.08	10048	6.2	2.1	1:1177
4	1332	+ 02 00	+0.09	—10.55	— 2.61	12491	7.8	1.6	1:1149
5	1393	+ 02 00	+0.50	—15.03	— 0.20	14830	9.2	1.4	1:987
6	774	+ 03 33	+0.52	—17.20	+ 3.05	17474	10.9	1.7	1:1000
7	400	+ 08 13	+0.09	—18.27	+ 1.03	19831	12.3	1.4	1:1084
8	389	+ 07 06	+0.08	—18.61	+ 6.06	23535	14.6	2.3	1:1203
9	1839	+ 09 32	+0.25	—25.19	+ 4.22	26190	16.3	1.7	1:1025
10	1871	+ 09 52	—0.01	—30.37	+ 4.44	29629	18.4	2.1	1:965
11	2008	+ 10 42	+0.14	—38.28	+ 9.52	32964	20.5	2.1	1:836
12	2067	+ 11 42	+0.37	—38.58	+13.96	35986	22.4	1.9	1:877
13	C.L.41	+ 12 12	+0.39	—36.81	+15.20	38284	23.8	1.4	1:961
14	2292	+ 11 42	+0.77	—35.36	+14.34	40510	25.2	1.4	1:1063
15	2304	+ 10 42	+1.37	—31.88	+19.36	43469	27.0	1.8	1:1139
16	1699	+ 10 42	+1.00	—25.06	+18.91	46574	28.9	1.9	1:1484
17	566	+ 09 40	+1.23	—22.45	+19.42	48798	30.3	1.4	1:1644
18	1500	+ 09 05	+1.03	—21.01	+17.54	51169	31.8	1.5	1:1724
19	1488	+ 10 00	+0.68	—15.49	+17.99	53828	33.5	1.7	1:2267
20	937	+ 12 35	+0.94	—10.51	+13.44	56142	34.9	1.4	1:3291
21	958	+ 09 18	+0.98	— 8.22	+12.28	58304	36.2	1.3	1:3945
22	1115	+ 09 30	+0.64	— 4.61	+10.85	61004	37.9	1.7	1:5174
23	2476	+ 08 20	+0.36	+ 0.41	+ 9.97	64073	39.8	1.9	1:6420
24	C.L.124	+ 08 20	+0.64	+ 3.92	+ 9.48	64970	40.4	0.6	1:6332

0.64 feet, dividing this by 306 we get 0.0021 feet as the average error in elevation per station. The next two columns show differences of latitude and longitude. The greatest difference in latitude being 38.58 meters at station 2067, 22.4 miles from starting point and the station in the loop which is, within a few meters, the farthest south from point of beginning. This maximum difference is precisely where we should expect to find it and its direction is minus (too far south) just as it should be to substantiate the statement previously made that distances are always read too great, that the amount they are over read is more than the error of focal length, and that in consequence of this fact the focal length error should be neglected. As the latitude again increases with the return of the loop to starting point, we see the proof again in the gradual decrease in the amount of the differences, passing through zero point and changing its sign just before reaching the starting point.

If more proof were needed we have it in the longitude column. The greatest minus difference being at station 2803, which is nearly as far East as any station in the loop, then becomes almost nothing at station 400, a station nearly South of starting point, then changing its sign to plus as we proceed westward, approaches its maximum at station 2304 and maintains it for over three miles as the courses are nearly due North, attains its maximum at station 1702 (not shown in table but situated a short distance *S. W.* of 1699 as shown in cut of loop line stations) which is *the farthest West of any station in the loop*, and then gradually grows smaller as the lines bend eastward toward point of beginning.

Further confirmation is found in the comparisons made upon the stations lying between 1393, 774, 400, 389 and 1839 where the courses deflect sharply from the general direction of the loop courses. Comparisons of differences made upon these intermediate stations, show, that in every case when the line bends westward or eastward the error in latitude remains stationary; if the line turns northward this error decreases but immediately increases when the courses become southerly again. The differences of error in longitude increase, remain stationary or decrease in the same way as the line turns West, South, North or East respectively.

It seems unnecessary to bring up any more facts in this connection, but to put the cap sheaf on the argument I will state that among the hundreds of lines of stations whose coordinates are upon record in our Record Book, there is not one single exception to the fact that in lines run North and South the latitude is always more in error than the longitude, in the lines run east and west the reverse is the case, and the direction of the error is always greatest in the direction in which the line is computed.



Curves Representing Difference
OF
Azimuth, Elevation, Latitude and Longitude.

The ratios of the difference of coordinates, which is the square root of the sum of the squares, to the distance from starting point, are given in the last column of table. After the first four miles this ratio never gets as low as 1 in 800. The final closure of 1 in 6332 of the forty mile loop tells nothing of the accuracy of the work. Such a closure would be good in tertiary triangulation. It is sufficient proof however, if any were needed, that only the coordinates of stations approximately in a straight line should be adjusted in this manner. Only approximately straight lines were adjusted in this survey.

This holds good for surveys in which distances are measured with a chain or tape, and shows that every survey that can make any pretentions to accuracy must be based upon a geodetic survey. The text books tell how to adjust a closed polygon, but such adjustments are of questionable value. There is no way to adjust correctly a closed figure.

Up to Nov. 1, 1892, $35,473.33 have been expended for this survey. This includes instruments, office furniture, horse and wagon and keep, repairs, stationery etc., amounting to about $3500.00.

It is not possible to separate the expenditures so as to tell the cost of the triangulation, the Precise Levels, or the Topography. Their relative cost is pretty well indicated however by the cost of the field work of each, which is known.

There are 815 days upon which the note books show field work to have been done. Of these the

Topography occupied 471 days or 57.8%.
Precise Levels " 250 " " 30.7%.
Triangulation " 94 " " 11.5%.
Leaving 281 days devoted to office work.

It will not be far from the truth, to assume that the time spent in the office upon each survey is in proportion to the time spent in the field for the same survey. Making such an assumption, the above percentages would stand for the relative cost of each survey for both field and office work. The actual cost then of each survey we find to be as follows:

Topography	$20503.59	= $0.732	per acre.
Precise Levels	10890.31	= 0.277	per acre.
Triangulation	4079.43	= 0.145	per acre.
Total cost per acre		= $1.154.	

Assuming that there are eight lots to an acre, the owner of a lot will have been taxed for these surveys, nine cents for the Topography, three and one-half cents for the Precise Levels and two cents for the Triangulation, a grand total of fourteen and one-half cents. I know a poor philanthropist who is willing to return the amount of the tax to any property owner who feels that he has been defrauded.

The cost of the sewers in that portion of the city already sewered has been about $638.00 per acre. I think no engineer will question the wisdom of expending $1.15 for a survey for an improvement to cost $638.00. But this refers to sewers only, whereas the surveys are available for estimates upon all public improvements,

A discussion of the uses of the survey and of the means of obtaining the greatest benefit from them, is perhaps, the most profitable topic to talk about in connection with this paper and I had intended to offer a few suggestions in that connection myself, but the length of the paper is already too great and this and other inviting questions will have to be passed over. The fine results of the surveys must not be considered as due to the direction of one person. The work in the field and the work in the office has been done by four engineers* (not all employed at the same time) assisted by competent and faithful subordinates. Each of the engineers engaged upon the work is a member or exmember of this club. Each of them did a part of the Topography, two did the Precise Leveling, and one person all of the Triangulation. Only one party was in the field at the same time.

It may be said, quite likely it will be said, that the figures presented show only the results of the work done upon these particular surveys, that the data given have little bearing upon similar work done elsewhere and cannot be safely used in passing judgment upon the reliability of surveys similarly conducted. To how great an extent this is true, each one must be his own judge. It is not my purpose to decry other methods, or to defend the methods used on this survey, until they have been assailed, and need defence.

Our methods and results have been given you in the same manner we tried to do the work—the best way we knew how.

DISCUSSION.

Prof. J. B. Johnson:—Mr. Colby has here described in detail what I believe to be one of the most accurate and useful pieces of municipal survey work ever done in America, and one which reflects credit on the city and also on all those who have been connected with it. He is to be especially thanked for the full description here given of the work, as it may serve to indicate how other cities may profitably follow our example.

The method of carrying azimuth which the writer describes, is taught in all the engineering schools of any note in this country and hence his disparaging reflection on the teachers of surveying should

* O. W. Connet, O. W. Ferguson, E. J. Jolley, B. H. Colby.

have been saved to a more worthy purpose. His method is equivalent to saying that Ver. A is constantly used, 180° being added to the fore-sight reading when orienting on back-sight.

In discussing the "error due to focal length" in stadia measurements the writer of the paper assumes that this error is always in one direction and that it results in giving too small a distance.

But when the rod is graduated by measuring a base from the center of the instrument, of a length equal to the average length of shot between instrument stations, as was done in the case under discussion, there is no correction to be applied.

For all readings less than this distance the distance read is too small, and for all distances greater it is too large, the formula for this correction being

$$K = (c + f)(1 - \frac{B}{B^1})$$

where K = correction,

B = distance read on rod,

B^1 = length of base for which rod was graduated.

$c + f$ = distance from center of instrument to a point in front of the objective the distance f, or the focal length of the objective.

Since this correction is plus or minus as the distance read is shorter or longer than the standard base, it is difficult to see how making this twice as great as it is would in any way overcome the tendency, which the writer of the paper shows to exist, to read the distance too long.

If the rod were graduated on a base whose initial point is taken a distance f in front of the objective, then the readings of all distances would be correct, with this constant $c + f$ added to all readings. But the writer of the paper did not graduate his rod in this way.

The error in latitude was found to be 38 meters in a direct meridian distance of 12 miles, or say 10 feet to the mile. Since he averaged eight readings to the mile, the average error was 15 inches. This is just about the average value of $c + f$, so that the moral to be drawn is to graduate the rod as though this error were to be applied to every reading and then neglect to apply it. It is fortunate, therefore, that the focal correction is not twice as large as it really is, but that it is just what it is.

For experienced topographers I agree with the writer of the paper that much sketching is unnecessary, but for beginners, who have not learned to impress the appearance of the contour of the ground upon their minds, I believe sketches are very helpful.

The slide rule here described has been copied for the use of Students in Washington University but arranged for both distances and elevations in feet, (or any other common unit.) and I am free

to say that it furnishes the most expeditious method I have ever seen for reducing stadia observations. I believe Mr. Colby is to be credited with having made the first slide rule specially adapted to this purpose.

Mr. J. A. Ockerson:—Mr. Colby's paper on the "Recent survey of St. Louis" is so thorough that it is difficult to add much of value to what he has so ably presented.

His training on the U. S. Lake Survey and the Mississippi River Survey made him unusually well qualified to conduct the work which he has carried on with such good results.

The methods employed are essentially the same as those in use in the Mississippi River surveys of today, modified, of course, to meet the special problem in hand.

In listening to the paper as read, the impression came to my mind that the author found so many defects in the stadia method as to make it on the whole very unreliable. On reading the paper over carefully, however, I find that perhaps this impression was due to the fact that the paper deals almost entirely with the defects and does not emphasize the advantages. To those who are familiar with the use of the stadia the advantages are so real that it is not too much to say that they all hold it in high esteem and regard it as standing far above every other method of topographical work both as to accuracy and economy. The $c + f$ bugbear is easy to absorb if it is thought desirable to do so. But for maps of ordinary scale it is a refinement which adds nothing to their accuracy where the triangulation checks are as frequent as they should be.

Some of the conclusions drawn in the paper apparently have not sufficient evidence to fully prove them.

It is impracticable to lay down an invariable or even a general rule as to the time of day the wire intervals should be determined.

The amount of refraction and the time of greatest refraction are both variable and depend largely on the temperature and pressure of the atmosphere.

Given a uniform temperature of the air for a considerable period of time with an overcast sky, and wire intrevals could be determined at any time of day. A paved street or a granitoid side walk is probably as unfavorable a place to test wire intervals as could be found, particularly under a clear sky. Their absorption of heat raises the temperature of the adjacent strata of air, hence the bottom of the rod is apparently thrown up more than the top, which is farther away from the heating effect.

Or the reverse effect will obtain if the lower strata of air are the coldest.

For a survey like the one under discussion, where only one party

was in the field at time, where the features located are practically of a fixed and definite kind followed out to the end by the same observer, and where the observer plats his own notes within a few days after they were taken, it may be possible that topographic notes without sketches are ample. In work on a larger scale where several parties must be kept at work and join their work together at frequent intervals, where the features are irregular and varied, making a definite nomenclature impracticable; where lack of experience, training and difference in judgment in the several observers lead them to interpret the features differently; where the notes are platted by one not familiar with the ground, or where the observer plats his own notes months after they are taken, there is nothing more important, after the correct instrumental locations, than a good sketch. Even a very crude sketch would add much to the value of the most elaborate system of notes. Granted that the sketch is "always inaccurate", its inaccuray does not appear in the map as platted. Its function is simply to show the continuity of the features located and recall to the mind of the observer the relations of these features on the ground. To show what points of an irregular outline of woods, swamps, sand bar etc. are to be connected, to define and identify the multiplicity of sloughs, fences, roads etc., and to show the plan, and position of houses located by shots to one corner. Where these features are frequent and intricate, no system of notes made by different observers would be intelligible without a sketch. In fact it is found in practice that the notes made in the field are never as full as we would like to have them when we come to reduce them.

Therefore the better policy would be to make the notes as full as you can and then make as good a sketch as circumstances require and time allows.

The defect ascribed to figures on stadia rods having points would be true of any figure. It is of course impracticable to have a figure with out some limiting outline and, having this outline, the readings, as generally taken, will be influenced by it. It is probable that one form of figure would have a greater influence than another. Still it is more than likely that the defect is more imaginary than real.

In have examined the notes of four U. S. Engineers in this particular with the following results. Out of 5633 readings between stakes, 3885 were even and 1748 were odd number of meters, Ratio 2.2 to 1. Out of 24363 side shots, 18667 readings were even and 5696 were odd. Ratio 3.3 to 1. Leaving out the notes of one observer and using the other three, which are more nearly alike, and the ratios become 1.7 to 1 and 2.6 to 1 respectively. This shows that personal equation is an important function in these results. It should perhaps be stated here, that the form of stadia board marks used is practically the same as Fig. 5 which originated in U. S. Lake surveys nearly eighteen years ago.

The difference in the ratios of distances between stakes and side shots, or distances read to locate topographic features, are to be expected, as many of the latter, as outline of timber or swamp, points of elevation, etc., are quite well enough located if read to the nearest point of figure.

In analyzing the instrumental courses we find for three observers 2,419 even and 1,424 odd meters, or 995 more even readings than odd ones. The probabilities are, that there should have been 1921 readings of each. This however cannot be taken as a measure of the accuracy of the work for the chances of reading the distance slightly too great or a little too small are equal.

As a matter of fact it is too late to fall back on theory to find possible defects in stadia work. The actual results obtained with it in tens of thousands of instrumental checks prove beyond question that the objections urged against it are mere quibbles. The discrepancies may be expressed mathematically by a long row of decimals, but when applied to the map, which is the real test, they become wholly intangible.

In the survey of the Mississippi River it has long been the custom to keep a record of the instrumental checks as a means of rating each observer's work and as a measure of the accuracy of the work as a whole. In the work of 1891 the average discrepancy in the stadia work was 1 in 912—the average lengths of the circuits being 3781 meters. Azimuth discrepancy in 115 cases averaged 2.4 minutes.

The first systematic attempt to measure the discrepancies of stadia work was the investigation of Capt. H. M. Adams of the U. S. Lake Survey published in the Report of the Chief of Engineers, U. S. A., for 1876. In 141 lines averaging 2,450 meters each, the average discrepancy was found to be 1 in 649.

In the secondary triangulation work on the upper Mississippi River in 1892 the average error of closure of 72 triangles was 1.83 seconds. In this work a diamond-shaped cloth target was used, which gave excellent satisfaction. Its chief advantages are that it is phaseless and its peculiar shape makes it conspicuous and it has the advantage of adapting itself to the length of line, as the observer can make his pointings to such part of target as is distinctly visible.

The results obtained by Mr. Colby under such difficult circumstances, are remarkably good.

In the precise levelling of 1891 from St. Paul to Savanna, a distance of 301.2 miles, which was done by our fellow members, O. W. Ferguson, and A. L. Johnson, the probable error at the end of 301 miles was 0.045 feet or the probable error per kilometer was 0.625 m.m. Total actual deviation of the two lines was 0.108 feet.

The cost of the work per mile for field work and reduction was $21.12.

The cost of the city work as given by Mr. Colby is $45.38 per mile. This difference is largely accounted for by the difficulties encountered in work that is so frequently interrupted on the thoroughfares of the city.

The cost of the entire work seems to be excessive but is probably accounted for in the same way and the further important reason, that the work demanded much more detail than an ordinary topographical survey. At all events it can safely be said that the work was done as rapidly and as well as consistent with the requirements. Mr. Colby is too modest in his claims. While the progress and success of the work depended largely on his assistants, still the fact remains that the skill and judgment acquired by long experience in similar work made him particularly well fitted to plan, direct and carry to successful conclusion the work he has so well described. The club is certainly indebted to him for the valuable paper he has presented.

Mr. O. W. Ferguson:—For the ability of his production and for the completeness of his paper, on the recent geodetic, hypsometric and topographic survey of the city of St. Louis, read before this club on November 2nd., 1892, Mr. Colby is to be congratulated.

In topographic work the condition necessary for determining the wire intervals for any given distance is to have uniform atmosphere and consequently uniform refraction. This condition is easier to find in dry than in wet weather. We will have uniform and steady atmosphere when the sun is not shining and when the temperature of air and ground is the same. This obtains in the morning before the sun has hit the ground where the base is located, and on cloudy days. For good results too I would always prefer a little breeze in the atmosphere to a dead calm. After about 5 o'clock in the afternoon in March there arises a rapid cooling of the ground and partial condensation of the moisture in the atmosphere near the ground, through which the lower wire line of sight passes *more* than in that portion through which the line of sight of the upper wire passes. This causes the lower ray of light to be convex upward and gives too large an interval. About seven to eight o'clock in the morning, the same disturbance occurs but would usually, I believe, cause the interval to be too small.

Mr. Colby knows that I do not agree with him that it is not expedient to take sketches of many topographic features, but some others might not know it.

Every experienced topographer will or should as Mr. Colby says devise a short hand system of expressing topographic features and connections. But without a sketch it would require longer to explain in writing how "1 joins 9 etc.," to say nothing about the subsequent trouble of reading all of this writing in conjunction with the plotting, than it would to make a sketch; which, by the way, need not be very

accurate. This numbering does very well for following the sinuosities of a thalweg, but the place where a sketch is essential is where fences, houses, roads, barns, banks and thalwegs are, as it were, *swerled* out of the vortex of a cyclone: here a sketch with a few numbers and dates on it corresponding with numbers in the notes and where shots were taken will straighten out and bring together things that would never have gotten together, on paper, without it. Sketching takes some time, but not more than about ten per cent., depending on the topography. Where the topography is simple the sketch is made in about no time, or need not be made at all. The advantage of the sketch is that though not so accurate (however the creek generally is put on the proper side of the road) it is a kind of a universal language, read at a glance.

Mr. B. H. Colby:—Perhaps I should have emphasized more than I did, my belief in the great advantages possessed by the stadia method over all others. I hold that there is no other method of doing topographic work that can truly claim to be its rival, either in speed, economy or accuracy.

I wish to disclaim any intention of laying down "an invariable or even general rule" as to time of day wire intervals should be determined. The observations given simply warn us to be careful of the conditions of the atmosphere most likely to prevail during the early morning and evening hours. I must however be allowed to differ from my critics upon the question of field sketches. I have yet to see a piece of country that cannot be correctly taken and mapped without the aid of a field sketch aud in much less time.

Two expert topographers, each trained and accustomed to making field sketches before being employed upon the St. Louis Survey, have both discarded the sketches and are to-day as firm believers as myself in the method of taking notes without sketches.

I hold, therefore, that the opinions of those who have tried both ways are entitled to as much weight as the opinions of persons who have tried but one way. Not more than one-third of the notes taken were plotted by the topographer who took the notes and several months have passed between the date of survey and time of plotting the notes. If it were a matter of memory at all, I would say by all means make sketches, but it is the design of our method to leave nothing to the memory and our experience has shown that it can be done.

I am glad to know that the data given regarding the number of odd and even shots has led others to investigate the same subject. It is certainly remarkable that out of 24,363 side shots read by four different U. S. Engineers 18,667 should be even and only 5,696 odd.

The average discrepancy in the stadia work done on the survey of the Mississippi River in 1891 has been given as 1 in 912 and that of a

portion of the stadia work upon the U. S. Lake survey as 1 in 649. The Lake Survey work mentioned was co-ordinated and is therefore valuable as a comparison, but the Mississippi River stadia work was not co-ordinated and if allowed any value whatever as a test of the accuracy of the work it ought to have been stated that the stadia courses were plotted upon a scale of 1 in 10,000, and the discrepancies in closure (which includes errors of plotting by polar co-ordinates as well as the actual errors of the survey) scaled. Upon such a small scale where one-tenth of a millimeter equals one meter it is apparent that if the co-ordinates of the stations were computed a much different ratio of closure than 1 in 912 might be obtained.

The average closure of the triangles on the Survey of the Mississippi River Survey in 1892 is given as 1.83 seconds in comparison with the closure of triangles given on this survey. Judge the results after comparing the instruments used in measuring the angles. Survey of St. Louis, instruments had verniers reading to *ten seconds.* Mississippi River Survey instruments, had micrometers reading to *one-tenth of one second.*

The deductions in regard to focal length error made by Prof. Johnson are correct. In expressing my belief that if the focal length error were twice as great as it really is and then neglected, better results would be obtained, I overlooked the fact that in the study of the data from which my conclusion was drawn the error of focal length had, (by the coincidence of average distance between stadia stations being within five per cent., the same as the length of base used in determining wire interval) been practically eliminated.

From Prof. Johnson's analysis of the data given it seems clearly proved that in determining wire interval the instrument should be centered at a distance $(c + f)$ from end of base line and then no correction made for focal length. This method will give nearly correct results in practice. I am glad that the data I have been able to present in this connection are extensive enough to seem to warrant so general a conclusion.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

ENGINEERS' CLUB OF MINNEAPOLIS.

ANNUAL MEETING, JANUARY 12TH 1893:—The President W. A. Pike in the chair.

Mr. G. Andrews and Mr. Fred. Llewellyn were elected members.

Letters were read from the Cleveland and Milwaukee Clubs in regard to the exchange of membership rights; and referred to a committee consisting of Messrs. Hazen, Hoag, and Redfield to consider necessary change in constitution and by-laws to effect the above exchange.

A letter from Duluth Club regarding exchange of papers which are read before each society was read, and secretary instructed to effect the exchange.

The Secretary reported, as follows.

I am pleased to state that the last year has been a more than average successful one for the club although a less number of papers were read than last year; Two exceedingly interesting joint excursions with the St. Paul Club took place, one to the Gillette-Herzog M'f'g works in Minneapolis and the other to West Superior, Duluth and the Vermillion Range.

Four new members were elected and two more proposed, four members were dropped from the list for non-payment of dues: The total membership is twenty-eight:

Total receipts for the year..........................	$ 128.94
" disbursements..............................	130.31
Leaving a defecit of................................	$ 1.37 which

I take pleasure in donating to the club, making the accounts balance.

The Club has no debts what-so-ever but is obliged this year at an early date to pay the second installment of $1.00 per member to the World's Fair Engineers Congress, and of course the JOURNAL will claim its $2.75 for the coming year per member, the Engineering News and the Engineering Record were paid up to January 1st. and it is for the club to decide if they shall be continued, if so it requires ten dollars for this years subscription; this would make it necessary to assess each member four dollars to provide for running expenses also, —last years assessment was four dollars,

Respectfully submitted,

F. W. CAPPELEN, Secretary.

Report was accepted and Mr. Redfield was elected Auditor.

The following officers were elected for 1893:

F. W. Cappelen, President; John M. Hazen, Vice-President; Elbert Nexsen, Secretary and Treasurer; A. B. Coe, Librarian. Wm. A. Pike, Member Board of Managers of Ass'n of Engineering Societies.

Mr. Charles Steiner, C. E. of Zurich, Switzerland, as guest at the meeting then read a paper up on the utilization of Minnehaha Falls for power purposes.

Mr. Steiner having been a resident of Minneapolis only about eight months, on his visits to the celebrated Minnehaha Falls was struck by the apparent waste of the power hidden in the beautiful sheet of water tumbling into the ravine in Minnehaha Park. He proceeded to investigate and make a preliminary estimate based upon a flow of about 150 cubic feet per second as a minimum with an effective fall of 93 feet giving about 1,600 H. P. The cost of the improvement he estimated at $35,000.00 and could of course show a splendid prospective profit to anybody that might invest. Mr. Steiner met the Park Board and made his proposition to it, but got rather a cold shoulder.

His scheme would spoil the park, etc.

Mr. Steiner however proposed to beautify the park in many respects and let the falls run on exhibition, say a few hours three times a week.

The discussion brought out the fact that last year was an exceptional wet one and that in six or seven years so much water had not been seen go over the falls, but that for several years the entire amount of flowage in Minnehaha Creek could be taken care of in a box 12 x 24 in. and not more than one-half full.

By storing the necessary water however in the surrounding lakes and using it in dry seasons, Mr. Steiner proposed to overcome all troubles of that kind. But he had not considered the cost of establishing such reservoirs. He estimated also about $^{8}/_{10}$ cubic foot per second per square mile, which according to Mr. Fanning, was about double what he at best might expect. The estimated cost of his improvement was also considered too low.

Mr. Steiner was voted the thanks of the club.

He will in future take the subject up again in detail and try to form a stock company to carry out his scheme,

Adjourned. F. W. Cappelen, Secretary.

ENGINEERS' CLUB OF ST. LOUIS.

375th Meeting, January 4, 1893:—The club met at 8. p. m. at the club rooms, President Moore in the chair; seventeen members and three visitors present.

The minutes of the 373rd and 374th meeting were read and approved.

The Executive Committee reported the doings of their 139th meeting.

Communications from the Civil Engineers' Club of Cleveland, and the Wisconsin Polytechnic Society were read, in which they announced that they had adopted the by-law in relation to the exchange of members.

The subject set for the evening, "The Recent Survey of St. Louis: Its Methods and Results," was then announced as open for discussion.

The uses of the survey in regard to laying out city lots was discussed by Messrs. Johnson, Bouton, Colby and Hermann. Mr. Ferguson spoke of the desirability of having a survey advance ahead of the growth of the city. Messrs. Moore, Bouton and Hermann spoke of the difficulty of relocating the old points.

Mr. Ferguson read a discussion on the subject.

The difficulties in handling the instruments and obtaining accurate re-

sults were gone over and the troubles pointed out. Sketches were recommended as an aid in working up the notes.

Prof. Johnson read a paper in which the question of errors in precise leveling was gone over.

Mr. Ockerson described the methods and results obtained in the river work.

Mr. Jolley described some of his difficulties with the stadia rod and level.

Mr. Ockerson presented to the club a copy of his book, "The Mississippi River from St. Louis to the Sea." On motion, a vote of thanks was given Mr. Ockerson for his donation.

Adjourned. ARTHUR THACHER, Sec'y.

376TH. MEETING, JANUARY 18, 1893. The club met at 8 p. m., at the club rooms, President Moore in the chair; and twenty-six members and three visitors present.

The minutes of the 375th. meeting were read and approved.

The Executive Committee reported the doings of their 140th. meeting. Messrs. W. Allderdice, D. E. Condon, W. F. Schafer and I. A. Smith were dropped, and the election of J. W. Nier was cancelled for non-payment of dues. The dues for 1893 were fixed at the same amount as for 1892. The resignations of Messrs. Belcher and Caldwell were accepted.

Mr. Geo. H. Pegram then presented the paper of the evening on "The Bridge across the Arkansas River at Fort Smith." A full description of the construction of the bridge was given. The piers were built of concrete, using Portland cement, and the method of erection was shown and illustrated with drawings. The specifications were read and the tests of materials used were presented in tables. The iron work was described and full drawings showed the design and calculations.

Discussion followed by Messrs. Schaub, Ockerson, Seddon. Moore, Johnson, Pegram, Gayler and Russell.

Adjourned. ARTHUR THACHER, Secretary.

BOSTON SOCIETY OF CIVIL ENGINEERS.

NOVEMBER 16, 1892:—A regular meeting of the Society was held at its rooms, 36 Bromfield street, Boston, at 7:40 o'clock, p. m. President Henry Manley in the chair. 46 members and 13 visitors present.

The record of the last meeting was read and approved.

The Secretary read a communication from the Engineers' Club of St. Louis, calling attention to a by-law adopted by that club, which provides for the exchange of members among the societies members of the Association of Engineering Societies and asking this Society to adopt a similar by-law. On motion the communication was referred to the Board of Government.

The Secretary reported that the appropriation made at the last meeting for fitting up the library and reading-room would not be sufficient to fully carry out the work. On motion of Mr. FitzGerald the sum of $61.25 was added to the former appropriation.

On motion of Mr. Whitney the question of investing the permanent funds of the Society now on deposit, was referred to the Board of Government with full powers.

On motion of Mr. Howe, the thanks of the Society were extended to Hon. Henry L. Pierce and Mr. E. A. Cushing, Superintendent of the Walter Baker Chocolate Works, for courtesies shown the members on the occasion of the visit to the works.

Mr. E. K. Turner then read a paper entitled "Notes on English Railways." A discussion followed on the subject of the paper in which Messrs. FitzGerald, Doane and Allen took part.

(Adjourned.) S. E. Tinkham, Secretary.

December 21, 1892. A regular meeting was held at the Society Rooms, 36 Bromfield Street, Boston, at 7:40 o'clock, p. m. President Manley in the chair. 37 members and 15 visitors present.

The record of the last meeting was read and approved.

Messrs. T. Howard Barnes, John S. Hodgson and Arthur T. Safford, were elected members of the Society.

On motion of Mr. Howe, the Secretary was requested to convey the thanks of the Society to the Pope Manufacturing Co., and the Proprietors of the *Youth's Companion*, for courtesies shown the members on the occasion of the visit to their new buildings.

The Treasurer reported for the Board of Government that $1,285 of the permanent fund of the Society had been invested in 25 shares of the Merchants' Cooperative Bank of Boston.

The Secretary read a communication from the President of the General Committee of Engineering Societies, Columbian Exposition, enclosing a list of foreign Engineering Societies to which invitations had been extended to avail themselves of the Engineering Headquarters in Chicago during the World's Fair and asking this Society to make any additions it desired. The communication was accepted and placed on file.

Prof. Alfred E. Burton then read the paper of the evening entitled "Base line measurements with the Steel tape, with an introductory account of the use of other instruments." Prof. Burton exhibited the apparatus used by him for steel tape measurements and gave an account of the accurate results which he had obtained by its use.

After a short discussion in which Messrs. Freeman, Morrison and Whitney took part the Society adjourned.

S. E. Tinkham, Secretary.

WESTERN SOCIETY OF ENGINEERS.

298th. Annual Meeting, January 4th. 1893. The Annual Meeting of the Society was held at the Sherman House, at 6 p. m., January 4th. 1893, with President Isham Randolph in the chair and over 130 members and guests present.

The reading of the minutes of the last meeting was dispensed with and the Secretary reported for the Board of Directors the following members elected:

Geo. S. Govier, Victor Windett, Clarence L. Crabbs, Wm. David Pence.

The application of Mr. George David Stonestreet was placed on file.

The following resignations were received: W. S. Bates, Chas. C. Brokaw, I. S. Dunning, C. A. Arentz, E. W. Stern, Irving A. Stearns, John D. Hibbard, Morgan Walcott.

President Randolph drew attention to a matter of unfinished business

—the proposed amendment to the By-Laws, permitting exchange of membership between the Associated Societies, as submitted to us by the Engineer's Club of St. Louis, and already acted upon by other Societies. The amendment was printed in our November proceedings and remains to be brought up for action.

The President then called for the Secretary's report.

SECRETARY'S REPORT FOR 1892.

To the Western Society of Engineers:

The Society has held 11 meetings during the year 1892, including the Annual Summer meeting, and apart from that occasion there has been an average attendance of some 57 members and guests at the regular meetings of the Society.

The membership of the Society should now amount to 442 members, but owing to the delinquent list and 10 resignations now to take effect, this number will be reduced according to the results of any action taken by the Board of Directors.

We have, I regret to say, lost the following members by death; Col. Roswell B. Mason, K. F. Booth, Jonathan Phillips, and A. D. Whitton.

Notwithstanding the fact that indications of the early spring pointed to a limited addition to our membership list for the year, it is pleasant to record that 65 new members have been added to the rolls. I would draw the attention of the Society to the fact that in the records of such Societies as ours, this continued yearly increase in our strength, viewed from the basis of a per centum of our total strength is perhaps unexcelled in the annals of Engineering Societies.

The following papers have been presented during the past year in addition to the addresses delivered at the Annual Meeting in January last:

A written discussion by Mr. Horace E. Horton on the report of the Committee on "Bridge Legislation;" "The King of Salt Lakes" by Mr. Geo. W. Waite; "The Behavior of Iron Columns under High Temperatures," by Mr. A. Gottlieb; "A report on the Railway Problem of Chicago" by the committee appointed for the purpose, followed by Minority reports and Discussion; A contribution to the discussion on "An Enlarged Water-way between the Great Lakes and the Atlantic Seaboard," by Mr. Wm. Pierson Judson; "Cedar Block Pavements," by Mr. Thos. Appleton; Discussion of same by Mr. D. W. Mead; "Continuous Rails," by Mr. A. W. Wright; "Practical Tests of Compound Locomotives in Regular Service," Second paper by Mr. C. H. Hudson.

The regular meeting for April was held in Apollo Hall, Central Music Hall Block, for the purpose of discussing the Technical School question in connection with the Chicago University when Prof. Harper and other prominent men addressed the Meeting.

A special meeting was also held in June for a continuation of the discussion of the Report on the Chicago Railway Problem.

A Report was also presented from the Committee on "Badge, Seal, etc.," the material result of which will be reported this evening.

Progress reports have from time to time been rendered by the Standing Committees, and Amendments to the Constitution and By-Laws have also been passed.

JOHN W. WESTON, Secretary.

The Secretary read a number of letters of regret from invited guests. Upon the report of the Judges of Election being called for, the following was presented.

To the Western Society of Engineers:

Gentlemen:—We, the Judges of Election appointed by the President and board of Trustees of this Society met at the rooms of the Society to canvass the votes cast for Officers for the ensuing year.

The board of canvassers organized at 12:30 p. m., January 4th, 1893, and proceeded with its work. A total vote of 265 was cast by the Society. Five of these votes from delinquent members were rejected, leaving 260 ballots to be canvassed.

The result of the canvass of the ballots is as follows:

For President	Horace E. Horton,	67 votes,
" "	Robert W. Hunt,	190 "
For 1st Vice-President.	Chas. FitzSimons,	35 "
" " " "	H. A. Rust,	220 "
" 2nd " "	H. B. Herr,	230 "
" " " "	Henry Raeder,	24 "
" Sec'y & Libr.	Max E. Schmidt,	119 "
" " " "	John W. Weston,	136 "
" Treasurer,	H. L. Bridgman,	71 "
" "	E. J. Nourse,	183 "
" Trustee,	Geo. S. Morison,	141 "
" "	Isham Randolph,	115 "
" Society Badge No. 1,		25 "
" " " " 2,		104 "
" " " " 3,		6 "

Respectfully submitted,

A. N. POWELL,
JAMES J. REYNOLDS,
G. A. BUTLER.

President Randolph then announced that the following officers were elected:—

President, Robert W. Hunt.
1st Vice-President, H. A. Rust.
2nd " " Hiero B. Herr.
Secretary & Librarian, John W. Weston.
Treasurer, Edwin G. Nourse.
Trustee, Geo. S. Morison.

An informal recess was then taken to await call from Banquet room.

At 7:45 the members and guests partook of the dinner and after the last course, and according to the programme issued by the Entertainment Committee, Gen. FitzSimons, as Toastmaster, took charge and most successfully carried the meeting along.

Upon being called upon the retiring President Mr. Isham Randolph delivered an address.

Mr. Randolph next introduced Mr. Robert W. Hunt, who very happily thanked the Society for the honor it had done him, suggested what was before the Society this year and concluded by offering as a toast the "Western Society of Engineers."

General FitzSimons then introduced Gen. W. Sooy. Smith, who in the course of his preliminary remarks warmly eulogized Mr. Hay of Davenport, Iowa, who had done so much in investigating the components and qualities of Steel, and delivered an address on "The Future of the Engineering Profession."

Mr. O. Chanute was next introduced and spoke on the subject of the "Engineering Congress and Engineering Headquarters for 1893."

Upon call of General FitzSimons, brief remarks were made by Mr. Horace E. Horton and Mr. John Lundie and in response to a general desire Mr. L. E. Cooley addressed the meeting briefly on the subject of "Deep Water to the Atlantic."

This practically closed the meeting. The musical programme provided, proved a most attractive feature of the meeting of 1893, which was a decided success.

JOHN W. WESTON, Secretary.

THE CIVIL ENGINEERS' CLUB OF CLEVELAND.

NOVEMBER 8TH. 1892. The meeting was called to order by the Vice-President, Mr. Porter. The records of the last meeting were read and approved. The application of John W. Langley for active membership was read. The following amendment to Art. 4 of the Constitution was offered.

ARTICLE IV. EXCHANGE OF MEMBERS.

SECTION 8.—Any member of any other Society in the Association of Engineering Societies, in good standing, may become a member of this Club, when duly elected as described in Art. III, without paying the initiation fee, and with a release from the annual dues for such period, not over one year, as he may show by certicate he has paid in advance in the Society from which he comes (*provided such Society have conferred like privileges on members of this Club.*)

Signed { W. R. Warner.
A. H. Porter.
Chas. S. Howe.

On motion of Mr. Warner it was voted to strike out the last clause beginning "provided etc."

The tellers reported that John G. Oliver and Geo. C. Bordons had been elected active members and Charles Orr, an Associate Member of the Club. On motion of Mr Gifford it was voted that a committee of three be appointed by the chair to promote social intercourse among the members and report at the next meeting. The chair appointed Messrs. Gifford, Warner and Roberts. On motion of Mr. Bowler it was voted that a committee of three be appointed by the chair to take appropriate action on the death of our late member, Mr. Zenas King. The chair appointed Messrs. Bowler, Sargent, and Osborn.

The paper of the evening was read by Dr. Morley, Professor of Chemistry in Adelbert College, on the subject, "Weighing Gases."

Adjourned. CHAS. S. HOWE, Secretary.

DECEMBER 13TH. 1892. The meeting was called to order by Vice-President Porter. The records of the last meeting were read and approved. Mr. Bowler, chairman of the committee to take action upon the death of Zenas King reported as follows:—

WHEREAS, It has pleased the great Ruler of the Universe to call from us our highly esteemed fellow member Zenas King, one of the earliest members of the Club, a progressive and public spirited citizen, and a man of great mechanical and financial abilities, as attested by the establishment of the great manufacturing industry bearing his name, and located in this city.—

Resolved, that we express our sincere sorrow at the death of our Associate, that the community has lost a good and enterprising citizen, and The Civil Engineers' Club of Cleveland, a respected and honored member.—

Resolved, that we tender to his bereaved family, our heartfelt sympathy in their great affliction.—

Resolved, that these resolutions be placed on record in the minutes of the Society, and that the Secretary of the Club be requested to have them engrossed and a copy transmitted to the family of our deceased associate.

N. P. Bowler.
J. H. Sargent. } Committee.
F. C. Osborn.

On motion of Mr. Gobeille the resolutions were adopted.

The Secretary was directed to have them engrossed and sent to the family.

Mr. Gifford, Chairman of the Committee for Promoting Social Intercourse among the members reported as follows:—

To the Civil Engineers Club of Cleveland.

Gentlemen:—Your committee, appointed November 8th, to consider the question of "promoting social intercourse among the members of the club," beg to report as follows:

That so long as the Club is confined to its present crowded quarters they do not deem it advisable to attempt to enlarge its scope by introducing features of a social nature. They recognize however the desirability of better mutual acquaintance among the members and urge the older members to welcome new members at the meetings of the Club and new members to make themselves known when in attendance at the meetings. They would suggest that after a candidate has been elected member his proposers take pains to meet him at the first regular meeting thereafter and introduce him to the members of the Club as far as possible.

While the question of a social feature to the meetings of the Club may be held in abeyance for the present, the committee wish to state that individually they shall bear it in mind and when a more convenient season presents itself, will bring it up again.

Respectfully submitted,

Geo. E. Gifford.
E. P. Roberts. } Committee.
W. R. Warner.

After some discussion the report was adopted.

Mr. James Ritchie read a paper entitled, "Cross Ties on Railroad Bridges." A paper on the same subject had been received from Robert Gillham, C. E., of Kansas City, and was read by the Secretary. Mr. W. W. Sabin read a paper on "Fire Resisting Construction."

The tellers reported that Dr. John W. Langley had been elected an Active Member of the Club and that the Amendment to the Constitution had been adopted.

On motion of Mr. Warner a vote of thanks was tendered to Mr. Gillham for his paper and the Secretary was instructed to notify him.

Adjourned. CHAS. S. HOWE, Secretary.

JANUARY 10TH, 1893. The meeting was called to order by Vice-President Porter. The records of the last meeting were read and approved. The applications of E. C. Cooke, J. R. Bitner, Samuel Groves, W. W. Read, C. W. Foote and C. F. Uebelacker for active membership and A. J. Findley and James Wood for associate membership were read.

On motion of Mr. Ritchie the following committee on nomination of officers for the coming year was elected:

John Eisenmann, W. R. Warner, W. H. Searles, J. L. Gobeille and Frank H. Neff.

Dr. John W. Langley read a paper on, "Certain Physical Properties of Steel as related to its Composition."

Adjourned. CHAS. S. HOWE, Secretary.

CIVIL ENGINEERS' SOCIETY OF ST. PAUL.

10TH. ANNUAL MEETING, JANUARY 9, 1893:—The tenth annual meeting of the Civil Engineers' Society of St. Paul was held in the Society Library at 8 P. M. Thirteen members and three visitors present. President Woodman in the chair. Minutes of previous meeting dispensed

with. The three following resolutions were passed and the Secretary instructed to send copies of the same to interested parties :

1. *Resolved*, That the thanks of the Civil Engineers' Society of St. Paul are hereby extended to Mr. E. F. Wells and the other officers of the West Superior Steel Works ; also to Mr. A. S. Cooper, and the other engineers of the city of West Superior, for the courtesies shown the members of this Society on the occasion of their trip to West Superior, Nov. 11, 1892.

2. *Resolved*, That the thanks of the Civil Engineers' Society of St. Paul are hereby extended to Mr. Robert Angst, Chief Engineer, and Mr. Thomas Owens, Superintendent of the D. & I. R. R. R., for the favors and courtesies shown the members of this Society on their trip to Tower and Ely, Nov. 12, 1892.

3. *Resolved*, That the thanks of the Civil Engineers' Society of St. Paul are hereby extended to the Duluth Engineers' Club for the entertainment of the members of this society at Duluth on the evening of Nov. 12, 1892.

The reading and acceptance of the annual reports then followed.

REPORT OF PRESIDENT.

St. Paul, Minn., Jan. 7, 1893.

To the Civil Engineers' Society of St. Paul.

Gentlemen :—Our constitution appears to require that, at the end of each official year the officers forming the government shall report on the Society's affairs. The reports in detail by the Secretary, the Treasurer and the Librarian, embody all matters of chief interest and importance, and will be read in your hearing.

The largest success can come to such an undertaking as ours only when it supplies such a real need as to elicit spontaneous support and excite perennial interest. But this is expecting too much. It is expecting too much for the busy men in the profession of engineering, whose mental strain in the routine of daily work is not exceeded in any of the occupations of life, that they should always by preference turn for recreation to the calculus and to the preparation of learned papers filled with appalling formulæ, that may be supposed to afford a momentary pleasure to the Society. To answer frequent calls of this nature would not only crowd life with work, but shorten it, and it would at the same time be a sacrifice made at the additional cost of starving that side of the engineer's nature that almost always needs to be turned to the sun, that requires the warmth of social graces upon it, and the alleviating and humanizing influence of poetry, fiction, and literature in general.

One of our authorities on engineering subjects frankly said that he had forgotten nearly all the higher mathematics he ever knew. I think it is true that few engineers are great mathematicians, and that many are not even good ones. On the other hand, some of the greatest engineering conceptions have arisen in the minds of such men. It follows from these several considerations that the literary exercises of such a Society as ours should have the widest range, to meet all capacities and tastes, and that we would be benefited, especially from a social point of view, by a variety extending "from grave to gay, from lively to severe."

It is a creditable professional modesty that causes one to shrink from bringing forward his little thesis before critics that, though friendly, are constitutionally severe, before brothers, it may be, stronger in theory than himself, and, as Cassius said to Brutus, "older in practice, abler than himself to make conditions," but it may often happen that this modest flower of a man has a beauty peculiarly his own, and that if he would, he could give us more pleasure from a bit of his unprofessional experience, of his

ordinary life, or simply of his imagination, than any number of successive differentiations could bestow.

If we are to make very much of the literary side of our associated work it will be well to enlarge the field in this way, which can be done without at all infringing on the purely scientific domain, wherein we have had so many valuable contributions from our members hitherto. At present there is room for all.

However, it is not a prime necessity that we have this literary feature, though the meetings certainly are better attended and pleasanter for it. The chief value of our organization lies in the friendly touch, the community of intellectual interest, and, above all, in the concentration of professional opinion on questions of importance to the community around us. Even if our meetings were less frequent, or were not held at stated intervals at all, but only on call upon emergencies appealing to the profession, it still would be useful to keep up the organization, and in the long run cause it to become one of the institutions of our city in which a degree of pride should be generally felt.

To foster the growth of our library and reading room is another object worthy of your care and solicitude. It is like the planting of trees to shade our children's children—we have our reward partly in the hope of making a kind thought effective on those who may never know us otherwise. And in this connection I would offer the only suggestion that has occurred to me for extending our immediate usefulness: that we might, perhaps, be able to render a valuable service to students of engineering in our city (such a one as in my youth I would greatly have prized), by opening our reading room to them under prudent regulations.

EDWIN E. WOODMAN, President.

SECRETARY'S REPORT.

ST. PAUL, MINN., Dec. 31, 1892.

To the President of the Civil Engineers' Society of St. Paul.

SIR:—The attendance at our meetings since the summer recess has seemed to cast a faint shadow over our future prospects, but when we come to consider the actual results of the past year's association, as compared with those of the year before, we have reason to feel not altogether gloomy. To be sure, our resident membership has fallen off and our library has not expanded at the same pace, yet our total increase in membership has been greater, and we have made two interesting and well attended excursions—a new feature in our proceedings. The number of papers presented, three, has been the same, namely: "The Yellowstone Park," by Mr. Hollingsworth, read March 7; "The Red River of the North," by Mr. Davenport, presented April 4th; and "Caves and Tunnels in St. Paul," delivered by Mr. Wilson at the joint meeting of May 21.

Our visit to the Gillette-Herzog Manufacturing Co.'s works at Minneapolis in May, and to the extensive plants at West Superior and the iron mines of Tower and Ely in November, were pleasant and profitable.

Five regular meetings have been held, with an average attendance of twelve (12). Three meetings were adjourned without a quorum, but there were fair reasons for non-attendance in two cases. On both of these occasions, however, entertainment was in store that would have repaid some exertion to attend. There was one joint meeting with the Engineers' Club of Minneapolis.

Our membership statement is as follows:

Total membership from date of organization	76
Since deceased or missing	33

Number of members in touch with the Treasurer:

Jan. 1, 1892—	Resident	35
	Non-resident	8
Total		43

Increase during 1892	7
Total membership Dec. 31, 1892	50
Present distribution—Resident	31
Non-resident	19

Respectfully submitted, C. L. ANNAN, Secretary.

TREASURER'S REPORT.

ST. PAUL, MINN., Jan. 9, 1893.

President Civil Engineers' Society of St. Paul.

SIR:—I have to submit, herewith, my annual report for the year ending Dec. 31, 1892:

RECEIPTS.

Cash on hand Dec. 31, 1891	$ 36 12
Collections on account of dues and Journal assessments previous to 1892	82 06
Collections on account of dues for year 1892	63 00
" " " initiation fees	20 00
" " " keys sold to members	2 00
" " " subscriptions to Journai (1892)	28 50
Collections from Alphonse Barman, on account of dues and Journal assessments previous to 1891	7 77
Total	$239 45

DISBURSEMENTS.

For Journal assessments	$102 00
For subscriptions to engineering periodicals	17 29
For purchase of two indexes	3 75
For keys to room	3 00
For bookbinding	13 75
For stationery, printing, postage stamps, etc	16 25
For furnishing room	4 70
Total	$160 74
Cash on hand Jan. 9, 1893	78 71
	$239 45

At the close of the year 1891 the uncollected accounts standing on the books, including Alphonse Barman, were		$175 81
Of which sum there has since been paid	$ 89 83	
Leaving a balance of accounts one or more years old due the Society from members in good standing	85 98	
	$175 81	
		$175 81

The following table shows the items of charges against members during the year 1892, and collections made:

Charges.	Items.	Collections.
$ 35.00	Initiation fees	$ 20.00
147.00	Dues,	63.00
93.25	Journal assessments,	28.50
2.25	Keys,	2.00
277.00	Totals,	113.50
	Balance outstanding,	164.00
$277.50	Totals,	$277.50

BALANCE SHEET, DEC. 31, 1892.

Liabilities	None
Assets—Cash on hand	$ 78 71
Accounts against members for 1891, and previous years	85 98
Accounts against members for 1892	164 00
Four keys at 25 cents	1 00
	$329 69

Respectfully submitted, A. O. POWELL, Treasurer.

LIBRARIAN'S REPORT.

St. Paul, Minn., Jan. 6, 1893.

To the President of the Civil Engineers' Society of St. Paul.

I herewith submit my report as Librarian of the Society for 1892. The Library contains now 219 volumes, of which 19 are additions in the past year. This number includes the engineering periodicals for 1892, which will be bound as soon as completed. Besides this, the Library contains numerous pamphlets, of which a considerable number has been received the past year.

The Society passed a resolution last year authorizing the Librarian to purchase an additional bookcase whenever it became necessary, and this will be one of the first duties of the new Librarian, as all available room is now occupied.

The Library contains no copies of the publications of the American Society of Mechanical Engineers—one volume per year—and, as their reports contain exceedingly valuable information, not available otherwise, I would recommend that the Society subscribe for these publications, if they cannot be obtained free of charge, as seems probable.

Respectfully, A. Munster, Librarian.

The Librarian was instructed to provide bound volumes of the Transactions of the Society of Mechanical Engineers for the three immediately preceding years, and subscribe for the same for the present year.

The annual election resulted as follows:

President, George L. Wilson; Vice-President, J. D. Estabrook; Secretary, C. L. Annan; Treasurer, A. O. Powell; Librarian, A. Munster; Representative on Board of Managers for Association of Engineering Societies, C. J. A. Morris.

The President made the following appointments :

Examining Board—C. F. Loweth, A. O. Powell, E. E. Woodman.

Auditor of Accounts for 1892, W. C. Merryman.

Mr. Joseph S. Sewall, member of the American Society of Civil Engineers, designer and engineer in charge of construction of the bridge across the Mississippi river connecting Marshall avenue in St. Paul with Lake street in Minneapolis, informally presented some interesting data concerning that structure.

The bridge consists of two principal iron arch spans of 456 feet each, and the total length is 1,273 feet. A 20-ft. roadway is laid on 7-in. by 16-in. wooden stringers, and is designed to admit the passage of a 15-ton road-roller. There is a 5-ft. sidewalk on either side. The appropriation was limited to $150,000, and was to cover all preliminaries. The cost of the substructure (abutments resting on sandrock and pier on gravel), was $32,260; superstructure, $109,100. Portland cement was used only in freezing weather. Work was begun in October, 1887, and finished in May, 1889.

Mr. W. H. Wood, lately returned from a five years sojourn in Southern Mexico, touched upon the novel methods of promoting and carrying out engineering enterprises in the far south, as exemplified by the construction of the Mexican Southern Railway and the draining of the City of Mexico. In estimating for a proposed railroad line, to be built with English capital, 20 per cent. is allowed for engineering.

Meeting adjourned at 10:45 P. M. C. L. Annan, Secretary.

ASSOCIATION OF ENGINEERING SOCIETIES.
ORGANIZED 1881.

Vol. XII. February, 1893. No. 2.

CONTINUOUS RAILS.

BY AUGUSTINE W. WRIGHT, MEMBER WESTERN SOCIETY OF ENGINEERS.

[Read December 7, 1892.]

In June 1891 I stopped at Johnstown Pa., and saw Mr. A. J. Moxham, President of the Johnson Company. In conversation he asked me "What do you think of our new girder joint?" I replied that "I think it the best joint in the market for street rails but it is very expensive and I would *weld* my rails in place and do away with joints." He asked "What will you do with the contraction and expansion?" I replied: Trautwine states in his pocket book under the head 'A remarkable fact' never sufficiently accounted for, that rails if fastened to the cross-ties in the ordinary manner and securely riveted or fastened together, do not contract or expand. Mr. Moxham remarked, that is a most important fact and sent for Trautwine's pocket book. I was unable to find the item and promised to write to him upon my return to Chicago. A careful examination of the 1891 edition satisfied me that the statement had been taken out of the book and thereupon wrote Mr. J. C. Trautwine, Jr. for the reason and received a reply from him as follows:

3301 HAVERFORD STREET,
PHILADELPHIA, June 5, 1891.

MR. AUGUSTINE W. WRIGHT,

Dear Sir:—Messrs. John Wiley & Sons have forwarded to me your favor of the 1st. inst., and I am much obliged for your enquiry. It is now above seven years since I wrote the chapter on rail joints for my first edition and omitted the "remarkable fact," to which you refer. If I remember rightly, my reason for dropping it was that it seemed paradoxical and I failed to substantiate it. Looking up the matter now in my father's note books the only reference I can find there is the following extract from the Civil Engineers and Architects Journal of 1857 referring to a French Road.

The riveting of the rails, an operation which had been tried and abandoned in England, was almost the sole thing on which the gauge of the way depended. As an instance of the effect of expansion and contraction it was mentioned above 1000 yards of riveted rail had been known to become suddenly elongated so as to form a series of vertical and lateral curves which were quite impracticable until night fall lowered the temperature and thus reduced the additional length.

The paper read before our Engineers Club here was written by Mr. R. Taylor Gleaves of Lynchburg Va., and read Nov. 15, '90. It is now in type and will appear shortly and I will try to secure a copy for you. In his experiments there were some peculiar features, especially the leaving of ⅜ inch play below the spike heads and the cutting off and turning out of the rail ends at intervals either of which would seem to be sufficient to account for the disappearance of the expansion.

I have just written Mr. Gleaves asking some further information on these and other points and will advise you further when I hear from him. In the mean time I should be much obliged for any further light that you can throw upon the subject,

(Signed) Yours Truly,

JOHN C. TRAUTWINE, JR.

I wrote Mr. Moxham and sent him a copy of the above letter and advised that he make an experiment with 1000 linear feet or more.

I subsequently wrote to Mr. Moxham and called his attention to the following extract from "European Railways" by Zerah Colburn and Alexander Lyman Holley, than whom America has produced no greater authority upon steel (Page 96), they state—"on the other hand several interesting examples show that the fastenings may be sufficiently strong or that the heat absorbed by the rails may be so carried off by the ground as to keep the rails in place even without any allowance for expansion. I. K. Brunell has stated that he welded together 100 feet of bridge rail and riveted together another length of one-quarter of a mile. These were securely fixed to the longitudinal timbers and accurate gauges set at each end.

The result was conclusive that there was no accumulated motion either at the extremities or at any part of the two lengths. Barlow's saddle back rail, which is bedded into the ballast, is now riveted closely and firmly together for five or six miles, without any practical inconvenience from expansion. Mr. John Hawkshaw once erected a parapet 750 feet long formed of sheet iron plates nine feet long and one inch thick. This was firmly riveted together and held down tightly and was proved to retain its position perfectly under all actual variations of temperature when put down. " * * *"

Mr. Moxham then decided to make the experiment as described in the following paper and from it you will see he found no increased expansion:

Experiments on the Expansion of Continuous Rails.*

In the matter of track construction to-day, the question of paramount importance is that of the joint. For many years the question has been the rail. As this has received time and attention, one weak spot after another has been eliminated, and so great has been the pruning process that the one weak spot left, "the joint," is only the more glaring from the absence of many of its brothers in misfortune.

Known to be the weakest point in the structure, the question of the joint has had its full share of attention. It is not perhaps generally known, but is nevertheless a fact, that the joint of the formerly despised street-railway has already distanced its heretofore leader, the steam railroad; certainly in its practical application, if not in its scientific development.

The question of the best joint is not entirely a scientific question. It is also a commercial question, and it ceases to be scientific; when it ceases to be commercial it then becomes "*non est.*" All evil is comparative:

> "The little girl who had a little curl
> Right in the middle of her forehead,
> Who, when she was good, was very, very good,
> And when she was bad, was horrid,"

might have been either a little angel or a little devil, according to whether the conditions were favorable to her easy control or not. So with the joint. The joint of the steam road can be controlled—it is exposed and therefore accessible; that of the street road cannot; it is practically inaccessible. It has been proposed to overcome this by making it accessible by means of boxes with removable covers. Apart from the objection that this adds to the amount of street taken up by the track, the cost, if properly done, is almost prohibitive. I have been informed by the manager of one of our largest and most progressive street railway systems that, after a careful trial, it was found to be cheaper to take up the paving and tighten the joints once every few months than to pay the interest on the investment of the boxes.

The question of a good joint is embodied in very few words, to wit: "absence of motion," and it must be absence of motion of the cars as well as of the rails, particularly in the case of electric roads. If two rails be placed in perfect surface and alignment and closely abutted, and so held, the problem is solved. Not only must they be true to surface and line, but they must be abutted. It will not do to leave the usual expansion space. This can be quickly demonstrated by cutting a groove one-quarter of an inch wide in the head of the middle portion

* By A. J. Moxham.

of a rail. The surface and alignment are here true, but not abutted. A slight jar can be felt from the first; in a short time it becomes worse, and after continued use, bad and rapid wear, accompanied by a low spot, results. In this case there is no motion of the rails; the evil is resultant from the motion of the cars. This, however, goes without saying, as of course the cars are the destructive agency, and it is only emphasized because it is a very prevalent opinion that if the rails as laid to-day could only be held rigidly level, the problem would be solved.

A few words as to the evolution of the joint; ignoring the old stringer construction, the first leaf was taken from the steam road, at that time far in advance of street-railway construction, at least in this country. The girder rail of to-day was in general use abroad some time before it was adopted here; but when adopted here, its advent at once permitted the use of the ordinary splice bars, in which the bevel of the plates fitting between similairly beveled portions of the rail and drawn into place by bolts, provided the joint. So amply strong was this joint considered, that at first it was deemed capable of economy; the bars and bolts were made light and the bearing surface small. With the horse car it appeared satisfactory. The development of cable roads however, at once indicated the weakness of the early practice, and the size of the bars and bolts was increased, and much larger bearing surfaces provided, in the shape of channel splice bars. Electricity now appearing showed even this improvement inadequate. It was found that the wear was concentrated at the rail juncture, and a bar that had become useless because of actual wear at this point, showed no wear at the extreme ends. In other words, the wear was indicated by motion at the rail ends, and did not extend to the whole bar. The problem was then attacked on the theory of stopping all motion. In this, two points were essential:

First—To hold the rail against motion by means of the fastening bars; to which end it was necessary to:

Second—Hold the fastening bars against motion by means of the bolts.

As to the first; Not only were the bars made of great rigidity both vertically and laterally (for both are essential,) but they were made to *fit* the rail. If one of our readers will carefully examine an ordinary spilce bar after it is tightened up, he will be somewhat surprised at the result. Taking a thin piece of paper and trying to work it into the fit, he will probably come to the conclusion that he has not more than 50 per cent., of real bearing or fit, as compared with the apparent bearing. No matter whether the track comes from a careful or careless manufacturer, nor how rigid the inspection, the evil will be found: it is only a question of more or less. It is due to the absolute impossibility of

making a fit of rolled surfaces when the structure is rigid. A good machinist will tell you that even with the lathe or planer this is a difficult achievement, let alone without. To avoid this, a spring or yield was introduced, and this under conditions demanding rigidity as a sequence. In other words, the springing or yielding portion was in itself of great rigidity and only made to yield by excessive tightening power. Hence the bearings, while strong and rigid in themselves, were made to spring or yield to a fit when tightened home by bolts large in diameter and many in number; and to secure this very deep bars of great structural stiffness, which permit of two rows of bolts of large diameter, were developed. It must be remembered that this must all be embodied in the joint itself; to make a poor joint and then merely support it, has been proved a total failure.

As to the second point; properly holding the bars: A large number of bolts was the first development and increased size or diameter followed. A nut lock to prevent slackness has been experimented with. If without spring to take up, not only the slack of the nut, but also the stretch of the bolt, it is useless, and few, if any, exist with this desiderata. A bolt so large in diameter that it will not stretch, and threads well cut and tight fitting, so that the nut is not liable to turn, are to-day the best safeguards. Not only the size, but the location of the bolts, is an important factor. It is the jolt or impact of the car that loosens the nuts. The vibration passes along well-defined lines. If the bolts are located in the line of greatest vibration, the nuts will tend to turn more quickly than if located elsewhere. A double row of bolts with the lower row staggered gives excellent results. A single row does not suffice.

Such is the joint of to-day, structurally stiff, heavy enough to take up the jar of the blow without transmitting it all to the nuts, a yielding fit that tends to counteract all motion, and large bolts, carefully located with a view to vibration. In itself good, as it now stands, to a certain extent, capable of economical use, and far ahead of its brother on the steam road, even of the heaviest construction. But even so, *it will not do.* If not, query, "What then?" There is but one answer. *No joint at all.* While apparently a bold suggestion, it is at least worthy of thought and discussion. That the rail can be made continuous by mechanical means we know, but what of expansion and contraction? *We will do without it*; and that we can do so, the sequel I think will show.

To the credit of Mr. Philip Noonan, I think, belongs the first practical idea of a continuous rail. His theory, in a nutshell, may be described as gripping the rail at one end and permitting the wave motion or flow induced by passing trains to be, so to speak, rolled out before the train wheels, into a tension device that within certain limits holds

what it gets. He provides against danger of rupture by a spring device which limits the strain. He put his ideas to a test, built a considerable stretch of track (some three miles) on the Lynchburg and Durham Railroad, at or near Gladys Station, Va., and it to-day is in successfull use. Expert investigation and report indorses it in all essential particulars, though it is perhaps questionable whether the fastenings he used to make his rail continuous are strong and rigid enough to prohibit all yield. For details, those who care to investigate may be referred to a pamphlet on the subject, that can be obtained by addressing the inventor at the above named place.

At a glance, the problem of a street-railway differs from the steam road in that the former is surrounded by the roadbed, while the latter is, at least to a great extent, exposed. The effect of the surrounding roadbed is twofold.

First—By its great surface friction, it tends to hold the rail against change, stops all wave motion, and

Second—It to some extent modifies the temperature.

The problem was to find a measure of value for both. To this end the following experiment was made:

One rail in a section of track was so connected that it was in reality a continuons rail. One side of the track was taken instead of both, because it was thought the parellelism of the adjacent rail would at once indicate changes that were expected to occur, which perhaps other measurements might fail to disclose. The length was 1,160 feet, and the profile one that embodied level track, up grade and down grade. As the track was laid and in use, it was determined that it was best to make the rail continuous by a joint rigid and stronger than the rail, so as not to have to remove the whole roadbed. This because the roadbed, which was macadam, had become solidly packed, and represented normal conditions hard to obtain if once disturbed. Remember that when the experiment was made it was thought questionable whether the rail, when prevented from expansion and contraction, could be at all restrained by the roadbed; hence all the restraining power offered was to be retained. At the end of each separate rail the usual one-fourth of an inch had been left for expansion. This was filled by a carefully measured dog, made of the same section as the rail, cut to fill the space tightly, and then driven into place.

Now for the joints: These were to be stronger than the rail itself, and for connection body-bound machine-turned bolts were decided upon. The two side bars were of steel, $4 \times 1\frac{3}{4}$ inches thick, and 5 feet $4\frac{1}{4}$ inches long. The body-bound bolts were 18 in number, and $1\frac{1}{4}$ inches in diameter.

As is well known, one of the most difficult things in metal working is to secure a real fit between two surfaces. The usual work of a ma-

chine tool—be it lathe, planer or what not—is very far from accurate, as the introduction of templet work into a shop soon shows. Out of an ordinary selection of average machinists, it is rare to find one in ten capable of making a real fit, sometimes less. To insure an absolute fit was deemed a necessity. It was done as follows: A number of jigs were made having a hardened steel guide for the drill. With this the bars were drilled in pairs, and as drilled each bar carefully tested by the standard. The holes were drilled $^1/_{32}$ of an inch smaller in diameter than ultimately needed. The roadbed surrounding a joint being removed, one bar was clamped to the rail, and the holes (also $^1/_{32}$ of an inch small) were drilled through the web, using the bar as a guide. After the temperature of the parts was equalized, the adjoining bar was then adjusted and a rose-bit reamer carefully worked through the three holes. As quickly as one hole was completed the gauge was taken, and one of a series of machine bolts (previously turned to a standard slightly large) was accurately turned for this special hole; and so to completion. The accuracy of the work may be shown by the fact that after reaming if anything interfered with the equalized temperature (as for instance one bar being removed and laid in the shade) during the work, the bolts could not be put home. Each bolt was a driving fit. It took twenty-four hours to properly adjust each joint. The track was thus made continuous.

At five points along the line heavy stakes were firmly fixed in the ground, one on each side of the road, in the top of which were set small wire nails. A thin but strong cord was tightly stretched from stake to stake, the tops of which were several inches above the top of the rail. Directly underneath this line a mark was made on the head of the rail with a cold chisel. Measurements were taken from the stake to the chisel mark, and from the top of the rail to the tightly stretched cord. Observations were taken at these five points, in the manner indicated, throughout the whole summer.

The work was started on the 19th of March, and finished on the 25th of April, 1892. The average temperature during the work was 43.04°, the maximum 81°, and the minimum 10°.

The section of rail used in the track is of the girder type, 6 inches deep, weighing 78 lbs. to the yard. The rail is fastened to the ties by means of tie-plates, and the gauge is preserved by the tie-rods spaced 10 feet apart. The ties are spaced 11 to 30 feet apart, and the roadway is excellent macadam.

Anticipating the unknown, provision was made for a possible sudden stoppage of the line, by means of portable connecting tracks kept in readiness. In order to further explain whatever might occur, careful preparations were made to read the temperature of the rail at different parts above and below ground, during the experiment. As the

rail was in use, this was done by a special rail in the adjoining roadbed, and in order that the scope of investigation should be fully complete, the temperature was continuously taken at the head of the rail, at the lower flange of a six-inch rail, of a seven inch-rail and of a ten-inch rail, or its practical equivalent, a ten-inch I-beam. Simultaneously readings of temperature were taken as follows:

Air in the shade.
" " " sun.
Roadbed at a depth of seven inches.
" " " " " ten "

(The apparatus used for the purpose of these readings is fully illustrated in Drawings No. 4 and 5 before you.) Before using the thermometers they were tested for comparative readings by the immersing them all in the same bath, which was raised gradually from freezing point to the maximum limit of thermometers; simultaneous readings being taken at intervals of five degrees. It was not found necessary to make any comparative corrections, no difference greater than one-half degree being found. The correction for the stem exposed in the thermometers was in all cases so small, not amounting to more than one-quarter degree, that it was neglected. The thermometers were obtained from Queen & Co., and are graduated to one-quarter degree. The rails were imbedded in macadam, and in such a manner as to most closely resemble the conditions found in an actual roadbed. The thermometers were enclosed by a box with sides of wire netting admitting the air freely, and intended only to protect the thermometers from accidental breakage.

During the experiment many thousand readings were taken. Without wearying you with the dry, technical details of their repetition, the writer merely calls attention to the fact that a recapitulation of these readings, in the form of averages, is attached to this paper, and in such shape, that the engineering student to whom they will perhaps appeal, will find food for study. There are eight different comparisons. Speaking very briefly, it may be stated as the result of an analysis of some of these averages:

First--That the roadbed at ten inches depth averaged,

A.—During day readings (see Table No. 4.)

At 8 A. M. 1°.25 less than air in the shade.
" 12 M. 8°.52 " " " " " "
" 6 P. M. 1°.88 " " " " " " and

B.—During night readings (see Table No. 4A.)

At 6 P. M. 1°.93 less than air in the shade.
" 12 P. M. 8°.30 more " " " " "
" 6 A. M. 8°.09 " " " " " "

as was to be expected, the earth being colder than the air temperature during the day, and warmer during the night.

Second—That the flange and head of rail, as laid in the roadbed, differed from the air temperature as follows:

A—During day reading (see table No. 1.)

At 8 A. M.	Flange	2°.36	less	than	air.	Head	3°.13	less	than	air.
" 12 M.	"	3°.63	"	"	"	"	4°.40	"	"	"
" 6 P. M.	"	2°.19	more	"	"	"	5°.61	more	"	"

B—During night readings (see Table No. 2.)

At 12 P. M.	Flange	5°.93	more	than	air.	Head	4°.00	more	than	air.
" 6 P. M.	"	3°.94	"	"	"	"	2°.67	"	"	"

Comparison is always made with the air in the shade, because the irregularity of the sun's rays introduces disturbing elements so great as to hide the law. As a factor of correction, if desired the percentage of difference can be deduced from Table No. 3.

The slight analysis of the tables will suffice to prove to the practical railroad man that for all ordinary purposes, the rail may be assumed to be subject to nearly full air temperature, and that the roadbed will not suffice, as has been believed, to keep the rail temperature virtually regular. Steel is a far better heat conductor than earth, and, as the tables show, the whole rail (flange as well as head) closely follows the air temperatures. Readings taken over a long period, night as well as day, every fifteen minutes (in Table No. 6) give the whole kaleidoscope of changing temperature for the close student. With this fact before us one element of doubt has been removed; but it also proves that the heating of the sun in the day, and the cooling of its absence at night, leaves the expansion and contraction most certainly there.

Now for its effects. The experiment has proved absolutely and beyond cavil, that it is restrained and held by the surface friction of the surrounding roadbed. From first to last, from a temperature of 22° below freezing point (or 10°,) to a temperature of 89° above freezing point (or 121°,) extending from March to August, there was ***absolutely no movement of the track out of place.*** Even at the ends was this true; proving that not only will the roadbed hold the track as a complete structure, but that it will do it consecutively. Once bedded, it will hold a rail 10 feet or 30 feet, as well as one 1,100 feet. On this point there is no room for error. The expansion in 1,100 feet, if not neutralized, would equal 5¼ inches, under the conditions here stated, and 5¼ inches would throw the rail out of line 14 feet, if it were held at the ends and permitted to bow in the centre. An expansion of one rail would mean about 6 inches in 30 feet out of line. The query arises, "What has become of it?" It is existent, and like all force, it would flow to the point of least resistance. In the case of a street rail, bur-

ied in the roadbed, it is reasonabbe to believe this point is in a minute enlargement and reduction of the sectional area of the rail.

As to its effect upon the steel: Experts teach us that a variation of 7° in temperature, if held, would subject the rail to a stress of 1,000 pounds per square inch. Taking a track laid at the low temperature of 40° and subject to a maximum of 120°, or a variation of 80°, the stress is equal to less than 12,000 pounds per square inch; much less than the elastic limit, and less than the strain put upon an ordinary bridge, or similar structure. It would therefore appear that the effect on the steel would be harmless.

On the face of it, therefore, there is nothing to prevent us abutting our rails, and this is but the prelude to an absolutely continuous track —*one without joints*—the rails welded by electricity, or otherwise connected one to the other, up to such lengths as may be deemed best.

As to its practical application, many precautions suggest themselves. It must be remembered that a track so laid will be like a huge spring under tension, absolutely safe and harmless when restrained by the roadbed, but ready to spring like a shot from a cannon if, while in this condition, the roadbed be removed. The part of common sense would appear to be to limit the length of a continuous rail to, say, five hundred or a thousand feet, with specially devised expansion joints at these intervals; or if desirable to take up the paving for repairs on a very short piece, the following would be effective: first remove only a foot of paving, then with a hack saw cut out, say, six inches of rail, thus removing the tension or compression, as may be. This done, the rest of the roadbed could be removed, starting from the cut part of the track, without danger. Be this as it may, it should be borne in mind that chained lightning is not a nice plaything, and therefore a lightning conductor is sometimes handy.

One important saving that would be effected by a "track without joints" would be in the weight of the rail. A rail of 100 pounds per yard is to-day in use, and next year will be extensively used. Perhaps without their knowledge, the cause of this has been the street railroad men's dearly bought and sad experience with joints. The joint being defective, the effort has been made to secure such stability of track as to relieve the joints by means of a heavy rail. In a 100 pound rail there are but 30 pounds of wearing surface, of which not more than 18 pounds can be used before the rail will have to be thrown out; therefore there will be 82 pounds unused. For mere stiffness and rigidity, a 66 pound rail, if supported by the proper number of cross-ties, will answer every engineering demand, even of electric cars at high speed. Anything over this goes to the debit of "bad joints."

TABLE NO. 1.

DAY READINGS.

Variation between Flange, Head of Rail and Air (Thermometer shaded) for 8 A. M., 12 M., and 6 P. M.

GENERAL AVERAGE.

Month.	No. of Readings.	Flange of Rail.	Head of Rail.	Air (Shade).
April..........	57	48.°40	49.°18	49.°97
May...........	70	62.°76	63.°98	65.°17
June..........	46	78.°00	78.°95	79.°43
July	72	77.°57	77.°91	79.°54
August........	78	75.°17	75.°07	77.°68
September....	36	65.°88	65.°38	67.°11
	359	69.°13	70.°09	71.°79
		AVERAGE AT 8 A. M.		
April..........	19	42.°07	46.°50	41.°05
May...........	23	56.°97	52.°78	61.°91
June	17	71.°44	72.°26	74.°17
July	24	68.°07	65.°31	71.°50
August........	26	68.°80	69.°38	71.°19
September.....	12	63.°25	59.°70	53.°33
	121	61.°21	60.°44	63.°57
		AVERAGE AT 12 M.		
April..........	20	50.°00	50.°90	54·°20
May......... ..	23	64.°78	66.°71	69.°21
June...........	16	80.°59	82.°03	85.°53
July	24	79.°10	81.°27	83.°89
August........	26	79.°44	76.°00	84.°71
September	12	71.°50	72.°25	73.°29
	121	71.°91	71.°14	75.°54
		AVERAGE AT 6 P. M.		
April..........	20	52.°70	52.°28	53.°85
May....... ...	24	65.°85	65.°81	61.°10
June..........	14	84.°73	83.°88	78.°84
July	24	81.°79	81.°70	76.°68
August........	26	78.°40	79.°57	73.°83
September.....	12	71.°75	70.°04	68.°04
	120	72.°26	73.°84	69.°45

TABLE NO 2.

NIGHT READINGS.

Variations between Flange, Head of Rail and Air, for 6 P. M., 12 P. M., and 6 A. M.

GENERAL AVERAGE.

Month.	No. of Readings.	Flange of Rail.	Head of Rail.	Air (Shade).
May...........	37	59.°88	58.°75	56.°07
June..........	48	73.°76	72.°37	68.°32
July	71	74.°40	72.°93	68.°54
August........	75	74.°25	71.°70	68.°41
September.....	33	65.°76	63.°48	59.°63
	264	70.°74	68.°96	65.°60
	AVERAGE AT 6 A. M.			
May...........	12	54.°25	53.°58	49.°79
June	17	67.°41	66.°66	63.°00
July...........	24	67.°22	66.°08	60.°66
August........	25	67.°12	65.°99	62.°54
September	11	59.°27	58.°54	53.°13
	89	64.°50	63.°54	59.°23
	AVERAGE AT 12 P. M.			
May...........	13	58.°11	56.°77	54.°88
June..........	17	71.°97	69.°50	65.°38
July	23	72.°96	71.°30	66.°17
August........	25	71.°46	69.°90	66.°14
September.....	11	63.°86	62.°22	56.°90
	89	69.°15	67.°22	63.°22
	AVERAGE AT 6 P. M.			
May...........	12	67.°12	66.°08	63.°62
June..........	14	83.°64	82.°53	78.°21
July	24	82.°96	81.°35	78.°68
August........	25	80.°18	79.°26	76.°18
September.....	11	72.°31	70.°59	68.°86
	86	78.°69	77.°42	74.°75

TABLE NO. 3.

SIMULTANEOUS RECORDS

of Air Temperature exposed to the Sun and in the Shade.

GENERAL AVERAGE.

Month.	No. of Readings.	Air (Shade).	Air (Sun).
August	60	77.°96	82.°00
September	30	65.°40	73.°38
	90	77.°11	79.°15
	AVERAGE AT 9 A. M.		
August	20	69.°25	105.°45
September	10	59.°50	60.°55
	30	66.°00	90.°48
	AVERAGE AT 12 M.		
August	20	82.°79	98.°87
September	10	73.°75	93.°85
	30	81.°10	97.°20
	AVERAGE AT 6 P. M.		
August	20	80.°47	75.°70
September	10	69.°05	66.°30
	30	76.°66	72.°56

TABLE NO. 4.

DAY READINGS.

Earth Temperatures at 7 and 10 inch depths, and simultaneous Air Temperatures; air taken in shade only.

GENERAL AVERAGE.

Month.	No. of Readings.	Earth 10 in.	Earth 7 in.	Air (Shade).
July	72	71.°74	71.°46	79.°11
August.........	18	66.°79	67.°72	76.°73
	90	69.°62	70.°71	78.°66
	AVERAGE AT 8 A. M.			
July	24	69.°83	69.°43	71.°52
August.........	6	70.°00	69.°50	69.°50
	30	69.°86	69.°45	71.°11
	AVERAGE AT 12 M.			
July	24	72.°00	72.°62	75.°97
August.........	6	71.°00	72.°00	82.°83
	30	71.°83	73.°23	77.°35
	AVERAGE AT 6 P. M.			
July	24	75.°91	78.°79	77.°81
August.........	6	76.°08	78.°33	77.°83
	30	75.°93	78.°70	77.°81

TABLE NO. 4A.

NIGHT READINGS.

Earth Temperatures at 7 and 10 inch depths, and simultaneous Air Temperatures.

GENERAL AVERAGE.

Month.	No. of Readings.	Earth 10 in.	Earth 7 in.	Air (Shade).
July	71	73.°6	73.°3	70.°6
August........	17	73.°1	74.°7	70.°8
	88	73.°5	73.°6	68.°3
	AVERAGE AT 6 A. M.			
July	24	70.°9	70.°5	61.°0
August.... ..	5	68.°9	69.°7	64.°7
	29	70.°5	70.°4	61.°6
	AVERAGE AT 6 P. M.			
July	23	76.°1	74.°8	78.°2
August.	6	76.°0	78.°3	77.°8
	29	76.°17	75.°5	78.°1
	AVERAGE AT 12 P. M.			
July	24	73.°8	74.°7	64.°7
August........	6	73.°8	75.°3	68.°8
	30	73.°8	74.°8	65.°5

TABLE NO. 5.

COMPARISON

Between Air Temperature and Rail-Head. Air in the Shade, Air in the Sun and Rail-Head.

GENERAL AVERAGE.

Month.	No. of Readings.	Air (Shade).	Air (Sun).	Head of Rail.
August........	60	77.°96	83.°61	74.°46
September	33	67.°51	70·°96	65.°70
	93	74.°19	78.°07	71.°22
	AVERAGE AT 9 A. M.			
August........	20	71.°75	78.°45	69.°80
September .. .	11	58.°18	60.°13	59.°68
	31	62.°88	67.°58	62.°21
	AVERAGE AT 12 M.			
August...... .	20	84.°77	111.°87	75.°70
September	11	73.°59	91.°81	66.°72
	31	75.°90	98.°41	68.°12
	AVERAGE AT 6 P. M.			
August........	20	77.°47	75.°70	78.°95
September	11	68.°86	66.°27	70.°59
	31	69.°90	67.°97	71.°36

TABLE No. 6.

CONTINUOUS RECORD OF 15 MINUTE TEMPERATURES.

Date.	Time.	Earth, 10 in.	Flange of Rail 5 in.	Earth, 7 in.	Flange of Rail.	Head of Rail.	Air.	Flange of 10 in. I beam
June 30.	8:00 A.M.	68.°0	66.°0	67.°0	65.°0	64.°5	63.°0	66.°0
"	8:15 "	68.°0	66.°0	67.°0	65.°0	64.°5	63.°0	66.°0
"	8:30 "	68.°0	66.°0	67.°9	65.°0	64.°0	62.°5	66.°0
"	8:45 "	68.°0	66.°0	67.°0	65.°0	64.°0	62.°5	66.°0
"	9:00 "	68.°0	66.°0	67.°0	65.°0	64.°0	62.°5	66.°0
"	9:15 "	68.°0	66.°0	67.°0	65.°0	64.°0	62.°5	66.°0
"	9:30 "	67.°0	66.°0	67.°0	65.°0	64.°0	63.°0	65.°5
"	9:45 "	66.°5	66.°0	67.°0	65.°0	64.°0	64.°5	65.°0
"	10:00 "	67.°0	66.°0	67.°0	65.°0	65.°5	66.°5	66.°0
"	10:15 "	68.°0	66.°0	67.°0	66.°0	66.°0	68.°5	66.°0
"	10:30 "	67.°5	66.°5	66.°5	66.°0	67.°0	68.°5	66.°5
"	10:45 "	67.°5	67.°0	66.°5	66.°5	67.°5	70.°0	67.°0
"	11:00 "	67.°5	67.°0	66.°5	67.°0	68.°0	70.°5	67.°5
"	11:15 "	67.°5	67.°0	67.°0	67.°5	67.°0	66.°0	68.°0
"	11:30 "	67.°0	67.°0	67.°0	67.°5	67.°0	65.°0	67.°5
"	11:45 "	67.°5	67.°5	66.°5	67.°5	68.°0	69.°0	67.°5
"	12:00 M.	67.°5	68.°0	66.°5	68.°0	69.°0	72.°0	68.°0
"	12:15 P.M.	67.°0	68.°0	67.°0	69.°5	70.°0	72.°0	69.°0
"	12:30 "	67.°0	68.°25	67.°0	69.°5	70.°0	71.°5	69.°0
"	12:45 "	67.°0	68.°25	67.°25	69.°5	70.°0	70.°75	69.°0
"	1:00 "	67.°0	68.°25	67.°5	69.°75	70.°0	69.°5	69.°0
"	1:15 "	67.°5	68.°25	67.°5	69.°0	70.°0	69.°0	69.°0
"	1:30 "	67.°5	68.°25	67.°5	69.°0	70.°0	68.°0	69.°0
"	1:45 "	68.°0	68.°25	67.°5	69.°0	69.°5	67.°5	69.°0
"	2:00 "	68.°0	68.°25	68.°0	69.°0	68.°5	67.°5	69.°0
"	2:15 "	68.°0	68.°0	68.°5	69.°0	68.°0	65.°0	69.°0
"	2:30 "	68.°0	67.°5	69.°0	69.°0	68.°0	65.°0	68.°5
"	2:45 "	66.°0	67.°5	69.°0	69.°0	68.°0	66.°0	68.°5
"	3:00 "	68.°0	68.°0	69.°0	69.°0	70.°0	71.°5	68.°5
"	3:15 "	68.°0	68.°0	69.°0	69.°0	70.°0	69.°5	69.°0
"	3:30 "	68.°5	68.°5	69.°0	69.°5	70.°0	71.°0	69.°5
"	3:45 "	68.°5	68.°5	69.°0	70.°0	70.°0	71.°0	69.°5
"	4:00 "	68.°5	68.°5	69.°0	69.°5	71.°0	73.°0	69.°5
"	4:15 "	68.°5	68.°5	69.°5	69.°5	71.°0	75.°0	70.°0
"	4:30 "	68.°5	68.°5	69.°0	69.°5	71.°0	75.°0	70.°0
"	4:45 "	68.°5	68.°5	69.°0	69.°0	71.°5	72.°0	70.°0
"	5:00 "	68.°5	68.°5	69.°0	70.°0	70.°0	71.°0	69.°5
"	5:15 "	68.°5	68.°5	69.°5	70.°0	69.°5	70.°0	69.°5
"	5:30 "	68.°5	68.°5	69.°5	70.°0	69.°5	70.°0	69.°5
"	5:45 "	68.°5	68.°5	69.°5	70.°0	69.°0	70.°0	69.°5
"	6:00 "	68.°5	68.°5	69.°5	69.°5	69.°0	70.°0	69.°5
"	6:15 "	68.°5	68.°5	69.°5	69.°0	68.°5	68.°5	69.°0
"	6:30 "	68.°5	68.°0	69.°5	69.°0	68.°5	68.°5	69.°0
"	6:45 "	68.°5	68.°0	69.°0	69.°0	68.°0	67.°0	68.°5
"	7:00 "	68.°5	67.°5	69.°0	68.°5	68.°0	65.°5	68.°5
"	7:15 "	68.°5	67.°5	69.°0	68.°5	68.°0	65.°5	68.°0
"	7:30 "	68.°5	67.°0	69.°0	68.°0	67.°0	65.°0	68.°0
"	7:45 "	68.°5	67.°0	69.°0	68.°0	67.°0	64.°5	68.°0
"	8:00 "	68.°5	67.°0	69.°0	67.°5	67.°0	64.°0	67.°5
"	8:15 "	68.°5	68.°0	69.°0	67.°5	66.°5	63.°5	67.°5

TABLE No. 6.—*Continued.*

Date.	Time.	Earth, 10 in.	Flange of Rail 5 in.	Earth, 7 in.	Flange of Rail.	Head of Rail.	Air.	Flange of 10 in. I beam
June 30.	8:30 P. M.	68.°5	67.°0	68.°5	67.°5	66.°0	63.°0	67.°5
"	8:45 "	68.°0	66.°5	68.°5	67.°0	66.°0	63.°0	67.°0
"	9:00 "	68.°0	66.°0	68.°5	67.°0	66.°0	63.°0	67.°0
"	9:15 "	68.°0	66.°0	68.°5	66.°5	65.°5	63.°0	67.°0
"	9:30 "	68.°0	66.°0	68.°0	66.°5	65.°5	63.°0	67.°0
"	9:45 "	68.°0	66.°0	68.°0	66.°0	65.°0	62.°5	66.°5
"	10:00 "	68.°0	66.°0	68.°0	66.°0	65.°0	62.°5	66.°5
"	10:15 "	68.°0	66.°0	68.°0	66.°0	65.°0	62.°0	66.°0
"	10:30 "	68.°0	66.°0	68.°0	65.°5	64.°5	62.°0	66.°0
"	10:45 "	68.°0	65.°5	67.°5	65.°5	64.°5	61.°5	66.°0
"	11:00 "	68.°0	65.°5	67.°5	65.°5	64.°5	61.°5	66.°0
"	11:15 "	68.°0	65.°5	67.°5	65.°0	64.°0	61.°5	66.°0
"	11:30 "	67.°5	65.°0	67.°5	64.°0	63.°0	58.°0	65.°5
"	11:45 "	67.°0	64.°5	67.°0	63.°5	62.°5	58.°0	65.°0
"	12:00 "	66.°5	64.°5	67.°0	63.°0	62.°5	58.°0	65.°0
July 1.	12:15 A. M.	66.°5	64.°0	66.°5	63.°0	62.°0	58.°5	64.°5
"	12:30 "	66.°0	64.°0	66.°5	62.°5	62.°0	58.°0	64.°5
"	12:45 "	66.°0	64.°0	66.°5	62.°5	61.°5	58.°0	64.°5
"	1:00 "	66.°0	64.°0	66.°0	62.°5	61.°5	58.°5	64.°5
"	1:15 "	65.°5	64.°0	66.°0	62.°0	61.°5	58.°0	64.°0
"	1:30 "	66.°0	63.°5	66.°0	62.°0	61.°5	58.°0	64.°0
"	1:45 "	66.°0	63.°5	66.°0	62.°0	61.°5	58.°0	64.°0
"	2:00 "	66.°0	63.°5	65.°5	62.°0	61.°0	58.°0	64.°0
"	2:15 "	66.°0	63.°5	65.°5	62.°0	61.°0	57.°5	64.°0
"	2:30 "	65.°5	63.°5	65.°5	62.°0	61.°0	57.°5	63.°5
"	2:45 "	65.°5	63.°5	65.°0	62.°0	61.°0	57.°5	63.°5
"	3:00 "	65.°5	63.°5	65.°0	61.°5	61.°0	57.°5	63.°5
"	3:15 "	65.°5	63.°0	65.°0	61.°5	61.°0	57.°5	63.°0
"	3:30 "	65.°5	63.°0	65.°0	61.°5	61.°0	57.°0	63.°0
"	3:45 "	65.°5	63.°0	64.°5	61.°5	61.°0	57.°0	63.°0
"	4:00 "	65.°5	63.°0	64.°5	61.°5	60.°5	57.°0	63.°0
"	4:15 "	65.°5	62.°5	64.°5	61.°0	63.°5	57.°0	63.°0
"	4:30 "	65.°0	62.°5	64.°5	61.°0	60.°5	56.°5	63.°0
"	4:45 "	65.°0	62.°5	64.°5	61.°0	60.°5	57.°0	63.°0
"	5:00 "	65.°0	62.°5	64.°0	61.°0	60.°5	57.°0	62.°5
"	5:15 "	65.°0	62.°5	64.°0	61.°0	60.°5	57.°0	62.°5
"	5:30 "	65.°0	62.°5	64.°0	61.°0	60.°5	57.°0	62.°5
"	5:45 "	65.°0	62.°5	64.°0	61.°0	60.°5	57.°0	62.°5
"	6:00 "	65.°0	62.°5	64.°0	61.°0	60.°5	57.°5	62.°5
"	6:15 "	65.°0	62.°5	64.°0	61.°0	60.°5	58.°0	62.°5
"	6:30 "	65.°0	62.°5	64.°0	61.°0	60.°5	58.°0	62.°5
"	6:45 "	65.°0	62.°5	64.°0	61.°0	61.°0	59.°0	62.°5
"	7:00 "	65.°0	62.°5	64.°0	61.°0	61.°0	59.°5	62.°5
"	7:15 "	64.°5	63.°0	63.°5	61.°5	61.°5	61.°5	62.°5
"	7:30 "	64.°5	63.°0	64.°5	62.°0	64.°0	66.°5	63.°0
"	7:45 "	65.°0	64.°0	64.°0	63.°5	66.°0	68.°5	64.°0
"	8:00 "	65.°0	65.°0	64.°0	64.°5	66.°5	70.°0	64.°0
"	8:15 "	64.°0	65.°5	64.°0	65.°0	66.°5	67.°5	65.°5
"	8:30 "	64.°0	66.°0	64.°0	65.°5	66.°5	68.°5	65.°5
"	8:45 "	64.°0	66.°25	64.°5	65.°0	66.°5	68.°5	66.°0
"	9:00 "	64.°0	66.°25	64.°5	65.°5	67.°0	70.°0	66.°0
"	9:15 "	64.°0	66.°25	64.°5	65.°5	67.°5	70.°0	66.°5
"	9:30 "	64.°0	68.°0	65.°0	66.°0	67.°5	71.°0	67.°0

TABLE NO. 6.—*Continued.*

Date.	Time.	Earth, 10 in.	Flange of Rail 5 in.	Earth, 7 in.	Flange of Rail.	Head of Rail.	Air.	Flange of 10 in. I beam
July 1.	9:45 A.M.	64.°0	68.°5	65.°0	66.°0	68.°0	72.°0	67.°5
"	10:00 "	64.°5	68.°5	65.°0	66.°5	68.°5	72.°0	68.°0
"	10:15 "	65.°0	69.°0	65.°0	67.°0	68.°5	70.°0	68.°5
"	10:30 "	65.°5	69.°0	65.°5	67.°0	68.°5	71.°5	68.°5
"	10:45 "	65.°5	69.°0	66.°0	67.°5	69.°0	71.°0	69.°0
"	11:00 "	65.°5	69.°0	66.°0	68.°0	69.°0	71.°0	69.°0
"	11:15 "	66.°0	69.°5	66.°0	68.°0	69.°0	73.°0	69.°0
"	11:30 "	66.°0	69.°5	66.°0	69.°0	70.°0	76.°5	70.°0
"	11:45 "	66.°5	70.°0	66.°5	70.°0	71.°0	77.°0	70.°0
"	12:00 M.	66.°5	70.°0	66.°5	70.°0	71.°5	77.°5	70.°0
"	12:15 P.M.	67.°25	70.°5	66.°75	71.°5	72.°5	70.°0	71.°5
"	12:30 "	67.°25	70.°5	67.°0	72.°5	73.°0	75.°0	71.°75
"	12:45 "	66.°5	71.°0	67.°0	73.°0	73.°0	77.°0	72.°0
"	1:00 "	67.°0	71.°25	67.°5	74.°75	75.°0	78.°0	72.°5
"	1:15 "	67.°0	71.°5	68.°0	75.°5	75.°25	76.°0	72.°5
"	1:30 "	67.°5	71.°5	68.°0	75.°5	75.°25	76.°0	73.°0
"	1:45 "	67.°5	72.°0	68.°5	76.°5	76.°5	76.°0	73.°0
"	2:00 "	68.°0	71.°5	69.°0	77.°5	78.°0	79.°0	73.°5
"	2:15 "	68.°0	71.°5	69.°0	78.°5	80.°0	80.°0	73.°5
"	2:30 "	68.°0	72.°0	69.°0	79.°0	80.°0	78.°0	73.°5
"	2:45 "	68.°5	72.°0	69.°5	80.°0	82.°0	82.°0	73.°5
"	3:00 "	69.°0	72.°0	70.°0	81.°0	83.°0	82.°5	74.°0
"	3:15 "	69.°0	72.°0	70.°0	81.°0	82.°0	80.°0	73.°5
"	3:30 "	69.°0	72.°0	71.°0	81.°0	82.°0	78.°0	73.°5
"	3:45 "	69.°5	72.°5	71.°0	81.°0	82.°5	78.°0	73.°5
"	4:00 "	69.°5	72.°5	71.°0	80.°5	82.°5	76.°5	73.°5
"	4:15 "	70.°0	72.°0	71.°0	80.°0	80.°5	74.°0	73.°5
"	4:30 "	70.°0	71.°5	71.°5	79.°5	79.°0	72.°0	73.°0
"	4:45 "	70.°0	71.°5	72.°0	79.°0	78.°5	73.°0	73.°0
"	5:00 "	70.°0	71.°5	72.°0	78.°5	78.°0	73.°0	73.°0
"	5:15 "	69.°5	71.°0	72.°0	78.°0	77.°0	71.°0	72.°5
"	5:30 "	70.°5	70.°5	72.°0	77.°0	75.°0	69.°5	72.°0
"	5:45 "	70.°0	70.°5	72.°0	77.°0	74.°5	69.°0	72.°0
"	6:00 "	70.°5	70.°5	72.°0	76.°5	73.°0	69.°0	72.°0
"	6:15 "	70.°5	70.°0	72.°0	76.°0	74.°0	68.°0	71.°5
"	6:30 "	71.°0	70.°0	72.°0	75.°5	74.°0	68.°0	71.°5
"	6:45 "	70.°5	69.°0	72.°0	74.°5	73.°0	66.°5	71.°0
"	7:00 "	70.°5	69.°0	72.°0	74.°0	72.°5	66.°0	70.°5
"	7:15 "	70.°5	68.°5	71.°5	73.°5	72.°0	64.°0	70.°5
"	7:30 "	70.°5	68.°5	71.°5	73.°0	71.°5	63.°5	70.°0
"	7:45 "	70.°5	68.°0	71.°5	72.°5	71.°0	62.°0	70.°0
"	8:00 "	70.°5	68.°0	71.°0	72.°5	70.°0	61.°5	69.°5
"	8:15 "	70.°5	67.°5	71.°0	72.°0	69.°5	60.°5	69.°0
"	8:30 "	70.°0	67.°0	71.°0	71.°0	69.°0	60.°0	69.°0
"	8:45 "	70.°0	67.°0	71.°0	71.°0	69.°0	59.°0	69.°0
"	9:00 "	70.°0	66.°5	70.°5	70.°5	68.°0	58.°0	68.°5
"	9:15 "	70.°0	66.°0	70.°5	70.°0	68.°0	57.°5	68.°0
"	9:30 "	70.°0	66.°0	70.°0	69.°5	67.°0	57.°0	68.°0
"	9:45 "	70.°0	65.°5	70.°0	69.°0	67.°0	56.°0	67.°5
"	10:00 "	70.°0	65.°5	70.°0	68.°5	66.°5	56.°0	67.°5
"	10:15 "	69.°5	65.°0	69.°5	68.°0	66.°0	55.°5	67.°5
"	10:30 "	69.°0	65.°0	69.°5	68.°0	65.°5	55.°5	67.°0
"	10:45 "	69.°0	65.°0	69.°5	67.°5	65.°0	55.°5	67.°0

TABLE NO. 6.—*Continued.*

Date.	Time.	Earth, 10 in.	Flange of Rail 5 in.	Earth, 7 in.	Flange of Rail.	Head of Rail.	Air.	Flange of 10 in. I beam
July 1..	11:00 P.M.	68.°5	64.°5	69.°0	67.°0	65.°0	55.°5	66.°5
"	11:15 "	68.°5	64.°5	69.°0	67.°0	64.°5	54.°5	66.°0
"	11:30 "	68.°5	64.°0	69.°0	66.°5	64.°0	53.°5	66.°0
"	11:45 "	68.°5	64.°0	68.°5	66.°0	64.°0	53.°0	66.°0
"	12:00 "	68.°5	63.°5	68.°5	65.°5	63.°5	52.°5	65.°5
July 2..	12:15 A.M.	68.°5	63.°5	68.°0	65.°5	63.°0	52.°5	65.°5
"	12:30 "	68.°5	63.°0	68.°0	65.°0	62.°5	52.°0	65.°0
"	12:45 "	68.°0	63.°0	67.°5	65.°0	62.°5	52.°0	65.°0
"	1:00 "	68.°0	63.°0	67.°5	64.°5	62.°0	52.°0	64.°5
"	1:15 "	68.°0	62.°5	67.°0	64.°0	62.°0	52.°0	64.°5
"	1:30 "	68.°0	62.°5	67.°0	63.°5	61.°5	52.°0	64.°5
"	1:45 "	68.°0	62.°5	67.°0	63.°5	61.°5	52.°0	64.°5
"	2:00 "	68.°0	62.°5	66.°5	63.°5	61.°5	52.°0	64.°5
"	2:15 "	67.°5	62.°5	66.°5	63.°0	61.°0	52.°0	64.°0
"	2:30 "	67.°5	62.°5	66.°5	63.°0	61.°0	52.°0	64.°0
"	2:45 "	67.°0	62.°0	66.°0	63.°0	61.°0	52.°0	64.°0
"	3:00 "	67.°0	62.°0	66.°0	62.°5	60.°5	51.°5	63.°5
"	3:15 "	67.°0	61.°5	65.°5	62.°5	60.°5	51.°5	63.°5
"	3:30 "	66.°5	61.°5	65.°5	62.°0	60.°0	51.°5	63.°5
"	3:45 "	66.°5	61.°0	65.°0	62.°0	60.°0	51.°5	63.°5
"	4:00 "	66.°5	61.°0	65.°0	61.°5	60.°0	51.°5	62.°5
"	4:15 "	66.°0	60.°5	64.°5	61.°5	59.°5	51.°0	62.°5
"	4:30 "	66.°0	60.°5	64.°5	61.°0	59.°5	51.°0	62.°0
"	4:45 "	66.°0	60.°5	64.°5	61.°0	59.°5	51.°0	62.°0
"	5:00 "	66.°0	60.°5	64.°5	61.°0	59.°5	50.°5	62.°0
"	5:15 "	66.°0	60.°5	64.°0	60.°5	59.°0	50.°0	62.°0
"	5:30 "	65.°5	60.°0	64.°0	60.°5	59.°0	50.°0	62.°0
"	5:45 "	65.°5	60.°0	64.°0	60.°5	59.°0	50.°0	61.°5
"	6:00 "	65.°5	60.°0	64.°0	60.°5	59.°0	50.°5	61.°5
"	6:15 "	65.°5	60.°0	63.°5	60.°0	59.°0	51.°5	61.°5
"	6:30 "	65.°5	60.°0	63.°5	60.°0	59.°0	52.°5	61.°5
"	6:45 "	65.°0	60.°0	63.°5	60.°0	59.°0	52.°5	61.°5
"	7:00 "	65.°0	60.°0	63.°5	60.°5	59.°5	54.°5	61.°5
"	7:15 "	65.°0	60.°5	63.°5	60.°5	61.°5	59.°5	61.°5
"	7:30 "	65.°0	61.°0	63.°0	61.°5	62.°5	61.°5	62.°0
"	7:45 "	65.°0	61.°5	63.°0	62.°5	63.°0	62.°0	62.°5
"	8:00 "	64.°5	61.°5	63.°0	62.°5	63.°5	63.°5	62.°5
"	8:15 "	65.°0	62.°5	63.°0	63.°5	64.°5	64.°0	62.°5
"	8:30 "	65.°0	63.°0	63.°0	63.°5	64.°0	64.°5	63.°0
"	8:45 "	64.°0	63.°0	63.°0	63.°0	64.°0	64.°5	63.°0
"	9:00 "	65.°0	63.°5	63.°5	63.°0	64.°0	65.°0	63.°0
"	9:15 "	65.°0	64.°0	63.°5	63.°5	64.°0	67 °5	63.°5
"	9:30 "	65.°0	65 °5	63.°5	64.°0	66.°0	71.°5	64.°0
"	9:45 "	65.°0	66.°0	63.°5	64.°5	67.°0	73.°5	64.°5
"	10:00 "	65.°0	67.°0	64.°0	65.°5	68.°0	74.°5	65.°0
"	10:15 "	65.°0	67.°5	64.°0	66.°0	68.°5	75.°0	65.°5
"	10:30 "	65.°0	68.°0	64.°0	67.°0	69.°0	76.°5	66.°0
"	10:45 "	65.°0	68.°5	64.°0	68.°0	70.°0	77.°5	66.°0
"	11:00 "	65.°0	69.°0	64.°5	68.°5	71.°0	77.°5	67.°0
"	11:15 "	65.°5	69.°0	65.°0	69.°0	71.°5	78.°5	67.°5
"	11:30 "	65.°5	69.°5	65.°0	70.°0	72.°0	78.°5	68.°0
"	11:45 "	65.°5	70.°0	65.°0	71.°0	72.°5	79.°5	68.°5
"	12:00 M.	65.°5	70.°0	65.°5	71.°0	72.°5	79.°5	68.°5

TABLE NO. 6.—*Continued.*

Date.	Time.	Earth, 10 in.	Flange of Rail 5in.	Earth, 7 in.	Flange of Rail.	Head of Rail.	Air.	Flange of 10in. I beam
July 2..	12:15 A.M.	66.°0	70.°5	66.°0	72.°5	74.°0	80.°5	69.°0
"	12:30 "	66.°0	71.°0	66.°0	73.°0	74.°5	81.°0	69.°5
"	12:45 "	66.°0	71.°0	66.°5	74.°0	75.°0	81.°5	70.°0
"	1:00 "	66.°5	71.°0	66.°5	75.°0	76.°0	80.°5	70.°0
"	1:15 "	66.°5	71.°5	67.°0	75.°5	76.°5	81.°5	70.°0
"	1:30 "	67.°0	72.°0	67.°5	76.°5	77.°5	82.°0	70.°5
"	1:45 "	67.°0	72.°0	67.°5	77.°0	77.°5	81.°5	70.°5
"	2:00 "	67.°5	72.°0	68.°0	77.°0	78.°0	82.°5	71.°0
"	2:15 "	67.°5	72.°5	68.°5	77.°0	78.°0	82.°0	71.°0
"	2:30 "	67.°5	72.°5	68.°5	77.°0	78.°0	81.°5	71.°0
"	2:45 "	68.°0	72.°5	69.°0	77.°0	78.°0	81.°0	71.°0
"	3:00 "	68.°0	72.°5	69.°0	77.°0	78.°0	81.°0	71.°0
"	3:15 "	68.°5	72.°5	69.°5	77.°5	78.°0	81.°0	71.°5
"	3:30 "	68.°5	72.°5	70.°0	77.°5	78.°0	80.°5	71.°5
"	3:45 "	69.°0	72.°5	70.°0	77.°5	78.°0	80.°5	71.°5
"	4:00 "	69.°0	72.°5	70.°0	77.°5	78.°0	80.°5	71.°5
"	4:15 "	69.°0	72.°5	70.°0	77.°5	78.°0	80.°0	71.°5
"	4:30 "	69.°5	72.°5	70.°0	77.°5	78.°0	79.°5	71.°5
"	4:45 "	69.°5	72.°5	70.°0	77.°5	77.°5	79.°0	71.°5
"	5:00 "	69.°5	72.°5	70.°0	77.°5	77.°5	78.°5	71.°5
"	5:15 "	69.°5	72.°5	70.°5	77.°0	77.°5	78.°0	71.°5
"	5:30 "	70.°0	72.°0	71.°0	77.°0	76.°5	77.°5	72.°0
"	5:45 "	70.°0	72.°0	71.°0	77.°0	76.°0	77.°0	72.°0
"	6:00 "	70.°0	72.°0	71.°5	76.°5	76.°0	77.°0	72.°0
"	6:15 "	70.°0	72.°0	71.°5	76.°5	75.°5	76.°0	71.°5
"	6:30 "	70.°0	72.°0	71.°5	76.°0	75.°0	75.°0	71.°5
"	6:45 "	70.°0	71.°0	71.°5	75.°5	74.°5	73.°0	71.°0
"	7:00 "	70.°0	71.°0	71.°5	75.°5	74.°0	72.°5	71.°0

General Average.

	No. of Readings.	Earth 10 in.	Flange of Rail 5 in.	Earth 7 in.	Flange of Rail.	Head of Rail.	Air.	Flange of 10 in. I Beam.
	241	67.°35	66.°69	67.°41	68.°39	68.°10	65.°71	67.°37

Maximum.

		71.°0	72.°5	72.°0	81.°0	82.°5	82.°5	74.°0

Minimum.

		64.°0	60.°0	63.°0	60.°0	59.°0	50.°0	61.°5

Difference.

		7.°0	12.°5	9.°0	21.°0	23.°5	32.°5	12.°5

Average Differences.

		......	......	......	....	....	......	× .02°+
		×	......	×	× .98°+	....	......	....
		......	......	......	....	×2.°39+	×	....

Table No. 7.

DAY RECORDS

Of Earth at 7 inches, Air (in Shade), and Flange of Rail.

General Average.

Month.	No. of Readings.	Earth 7 in.	Flange of Rail.	Air (Shade).
May	10	59.°80	62.°40	65.°40
June	74	73.°74	76.°71	78.°10
July	72	73.°95	77.°57	79.°55
August	18	73.°28	76.°05	76.°72
	174	76.°52	80.°88	82.°57

Average at 8 A. M.

Month.	No. of Readings.	Earth 7 in.	Flange of Rail.	Air (Shade).
May	3	55.°50	56.°50	63.°70
June	26	69.°35	69.°30	71.°67
July	24	69.°14	69.°29	70.°29
August	6	69.°50	67.°66	69.°50
	59	66.°75	68.°45	70.°49

Average at 12 M.

Month.	No. of Readings.	Earth 7 in.	Flange of Rail.	Air (Shade).
May	3	60.°33	65.°00	72.°66
June	25	73.°38	78.°90	84.°78
July	24	72.°79	80.°35	96.°35
August	6	71.°91	76.°83	82.°03
	58	70.°58	76.°84	92.°20

Average at 6 P. M.

Month.	No. of Readings.	Earth 7 in.	Flange of Rail.	Air (Shade).
May	4	62.°62	65.°00	61.°25
June	23	79.°13	83.°30	78.°21
July	24	82.°91	83.°49	79.°06
August	6	76.°66	84.°00	77.°83
	57	86.°50	82.°14	75.°57

TABLE NO. 8.

DAY RECORDS

Of Earth at 10 inches, Air (in shade), and Flange of 10 inch I *Beam.*

GENERAL AVERAGE.

Month.	No. of Readings.	Earth 10 in.	Air (Shade).	Flange of 10 in. I Beam.
July	72	72.°59	79.°27	74.°[illegible]
August........	78	71.°91	76.°42	72.°94
September.....	33	65.°12	66.°88	65.°12
	183	70.°94	75.°82	72.°84
		AVERAGE AT 9 A. M.		
July	24	69.°80	76.°93	69.°37
August........	26	65.°05	68.°64	69.°88
September	11	63.°18	58.°18	60.°25
	61	66.°57	67.°73	67.°73
		AVERAGE AT 12 M.		
July	24	72.°04	88.°08	77.°50
August........	26	70.°57	72.°74	73.°81
September....	11	64.°04	72.°40	65.°37
	61	69.°95	78.°73	73.°92
		AVERAGE AT 6 P. M.		
July	24	75.°91	78.°77	78.°20
August........	26	74.°15	77.°36	80.°76
September	11	68.°13	69.°04	68.°91
	61	74.°08	76.°37	77.°62

Mr. Wason of Cleveland stated at the last Annual Convention of the American Street Ry., Association.—In order to get as nearly as possible a continuous rail we made an experiment in the early part of the present year and put down about 1000 feet of track, riveting the joints with red hot rivets put in by boiler makers. The rails were placed end to end as close as we could get them, 56 pound rails spiked to the ties and six red hot rivets put into each joint. The joints were first brought together by inch bolts and then pulled home and then one by one the bolts were taken out and replaced with red hot rivets. That was on one of our suburban lines. It is true that it does not have a large amount of traffic but it was principally done to see whether the summer would have any effect in twisting it out of line. It was put down in March and is (October 23rd '92) just as straight now as when first put down.

The joints are absolutely imperceptible. In my opinion so long as you depend upon bolts which are bound to work loose in time the track will be in trouble. What the results will be in winter I do not know. The hot weather had no effect whatever upon it.

The greater portion of our tracks is laid in hot weather so that the stored force in the rail will usually be one of compression rather than tension. The foregoing statement of facts will warrant the electric welding of street railroad rails at least, and in my opinion steam railroads will ere long try the experiment.

A recent writer states that by the Inter State Commerce Commission statistics, there were at the end of June 1890 the following number of men employed in the maintenance of way of American Steam Railroads.

Carpenters	37,936
Section Foremen	27,129
Other Trackmen	157,036
	222,101

That one hundred thousand of this force could be dispensed with if they were relieved of the care of joints would be a conservative estimate, and the saving in the outlay for rails would be very great as they usually wear out first at the joints. The matter is one of such great importance that it is well worthy of investigation. We all know that with the ordinary joint fastening a due allowance for expansion must be made, but the ordinary joint does not fulfill the conditions as stated by John C. Trautwine.

The Johnson Co., have had large experience in electric welding and are now preparing a portable machine with which rails can be welded as laid in the track.

THE BIRTH OF A PROFESSION.

ADDRESS BY J. B. JOHNSON, RETIRING PRESIDENT ENGINEER'S CLUB OF ST. LOUIS.

[Delivered Dec. 21, 1892.]

When Watt invented the steam engine he revolutionized the world of industry and also of thought so far as this is occupied with things industrial. Out of this revolution has come a new profession. The practical bent given by this invention to all lines of applied science has stimulated the work of the pure scientists also, until we now have a world of established truth, before unknown or dimly dreamed, from which to draw perpetual applications to the ever increasing and more complicated demands of civilized life. With this rapidly growing world of scientific truth on the one hand, and the multifarious demands for new applications of it on the other, there must of necessity be evolved a class of men who make these applications their peculiar business, and these men are called Engineers. In other words, the engineer is one whose business it is to make new and useful applications of the materials and forces of nature, to the needs of society, in a safe, economical and scientific manner. The man who makes only old and familiar applications of these materials and forces is called a mechanic. The inventor makes new attempts at such applications his particular business but he cannot be trusted to do this with the certainty of producing an economic success. The unscholarly engineer solves his new problems in a tentative and unscientific manner, reaching success through expensive failure or through an extravagant use of materials, with great uncertainty as to his factors of safety. Scientific knowledge which is limited to one's own experience is extremely meagre and inadequate. It is the greatest conceivable folly and waste of energy and time to try to gain by experience what has already been proved beyond a peradventure and which is taught in all the schools. When a century of laborious experimenting may be learned in an hour under good instruction, it is nothing short of stupidity that would lead one to forego the instruction and to rely on personal experience. No amount of personal experience, or of native genius, can take the place of scholarly acquirements, neither can such acquirements replace the knowledge of methods, men, and things which comes only by experience.

That a great deal of an engineer's ordinary business can be learned

by experience there is no question, but by experience alone one would never become an Engineer. He can become a mechanic, but without such a knowledge of principles as would enable him to solve safely and economically new problems, I would not call him an engineer.

In short I should say that a vocation only becomes a profession when an acceptable performance of its duties demands the continuous exercise of scholarly acquirements. To the extent that such acquirements are not required, the business is a trade and not a profession. Thus dentistry, so far as the mechanical manipulations of extracting, making, and filling teeth are concerned, is a trade. So far as the giving of advice and deciding what should be done in given cases is concerned, this requires a continuous exercise of scholarly acquirements, and hence to this extent it is a profession.

The satisfactory discharge of the duties of the lawyer, the doctor, the minister, and the teacher do demand the continuous exercise of scholarly acquirements, and it is only in consideration of this fact that these employments are put into a separate category of employments and called professions.

If Engineering is to become a full-fledged profession its duties must be such as to demand scholarship for their satisfactory performance. If the engineer is expected to make new and useful applications of the materials and forces of nature in a safe, economical, and scientific manner, then surely the satisfactory performance of his duties does call for very extended scholarly acquirements. And if engineering has not as yet reached a very high professional standing in this country it is simply because engineers themselves have had too low an ideal of professional accomplishment. In this country nearly every man finds his level, and surely every class of men is estimated very nearly at its true relative worth.

In comparing the standing of Engineers in America with their status in European countries it is well to remember that this is a new and self-made country. That every man has been the architect (or engineer) of his own fortune and that the training our capitalists have had in making their way in the world has given them confidence in their judgments in all things material, so that they always stand ready to call in question any decision their Engineer may render. Abroad it is very different. Capital is almost wholly inherited, and the capitalist knows little of the practical adaptation of material means to industrial ends. He is therefore wholly at the mercy of his professional advisor, and so the Engineer comes to be a sort of autocrat, whose judgment is not to be questioned. But this ability, or assumed ability, of the employer is probably wholesome medicine for the Engineer, who is thus held to more strict economic requirements, very much to the benefit of the practice, on the whole. Perhaps no one thing has been

a greater factor in the development of current engineering practice in this country than the necessity which has been nearly always imposed of producing fair results with what would be regarded by the foreign engineer as wholly inadequate means. But just as the steam engine has wonderfully stimulated all lines of commercial activity by cheapening motive power, so the cheapening of engineering structures and means of transport has enabled this country to develop its resources at an unparalleled rate. I have therefore placed economy in design as one of the essentials of an engineering success. In fact our development has been so rapid that any one who could in even a small or inadequate way direct the work has not lacked for employment, and so thousands of men have come to be known as engineers who have but a mere smattering of scholarly acquirements.

Just after our civil war axemen became levelers, transitmen, resident, and chief Engineers on new railroads in a series of rapid promotions, and yet it was difficult to supply the demand.

The public in this country has always confused surveyors with civil engineers. A few years ago I dropped in on the annual meeting of the Association of Engineers and Surveyors in one of our Western States and I there learned the sharp distinction between these two classes. I found that a civil engineer was one who had used, or thought he could use either a level or a transit, as in laying out town lots, or in fixing the grade of a street or ditch, while the surveyor was one whose knowledge and confidence was confined to the needle compass and a Gunther's chain. This distinction was soberly and sharply drawn in their discussions and proceedings and since such were the only "Engineers" they had in their association it must have been generally held. This comes from calling the surveyor of a country village the "City Engineer." Since it is his official title he is evidently warranted in using it.

In analyzing the status of the Engineering profession in America, therefore, I conceive that we may divide the embarrassments under which we labor into two classes, those conditions outside our own ranks, and those inside. The most embarrassing external conditions are:—

1st:—The universal confusion of mind on the part of the general public as between a surveyor and a civil engineer; or between a mechanic or mechanical draughtsman and a mechanical engineer; or a mining Superintendent and mining engineer; or between an electrical mechanic and an electrical engineer.

2nd:—The confidence that all our capitalists have in their own judgments on all kinds of engineering questions, and their usual preference for a "practical" man who is not likely to try anything new. Their want of faith in new things comes from various and sundry losses resulting from having fallen a prey repeatedly to over confident invent-

ors and to patent sharks. The idea that new problems may be successfully solved without large primary losses has gained little credence as yet in the minds of the public.

The chief embarrassments from within from which our profession suffers are, as I conceive.

1st:—Too low an idea of professional accomplishment. Engineering is looked on as a trade to be learned rather than as a business requiring the continuous exercise of scholarly acquirements. And after having learned a trade we begin to demand the consideration usually given to learned professions. When we have, as a class, acquired these accomplishments, and have shown by our works that we can be trusted to solve new problems safely and economically, be sure the over credulous American public will quickly respond with its generous recognition.

2nd:—The failure, heretofore, to give due weight to both theory and practice in the young engineer's apprenticeship. The question has been either a course in an engineering school or a few years of any sort of hap-hazard engineering or surveying practice. Until we come to see that both a well-rounded course of school training and a symmetrical but varied line of experience are necessary for all young engineers, until such time our engineers will be unsymmetrical, lop-sided, partial successes. Some will have much theory which they cannot use, others will know how to do things in the old way but will halt and hesitate and only partially succeed when they venture to do something new. It is true the Engineering schools are doing a noble work for us, and our various Engineering Societies are kneading and cementing the members of this newly fledged profession into something like a professional body, but until our young graduates generally succeed in serving a sort of varied apprenticeship after leaving college, a kind of *wanderyahre*, in which they will gain a varied and symmetrical experience, they cannot hope to gain that full stature in the profession which is desirable and really essential to successful designing in new fields. The better class of Engineering schools are doing all that can be done with profit in school. They all have shops and laboratories and drawing rooms where the students themselves use the tools and the various testing machines; they go for weeks into the field and make surveys and lay out railroads in a more or less business way, but the methods of actual practice cannot be learned to any great extent except in actual practice. Every young engineering graduate should therefore change his employment for several years as fast as he clearly learns the theory and practice of the work on which he is engaged. One of the worst things he can do is to immediately obtain a long and steady job. This will fix him in a rut from which he can with great difficulty extricate himself. I do not mean he should scatter over much, but he

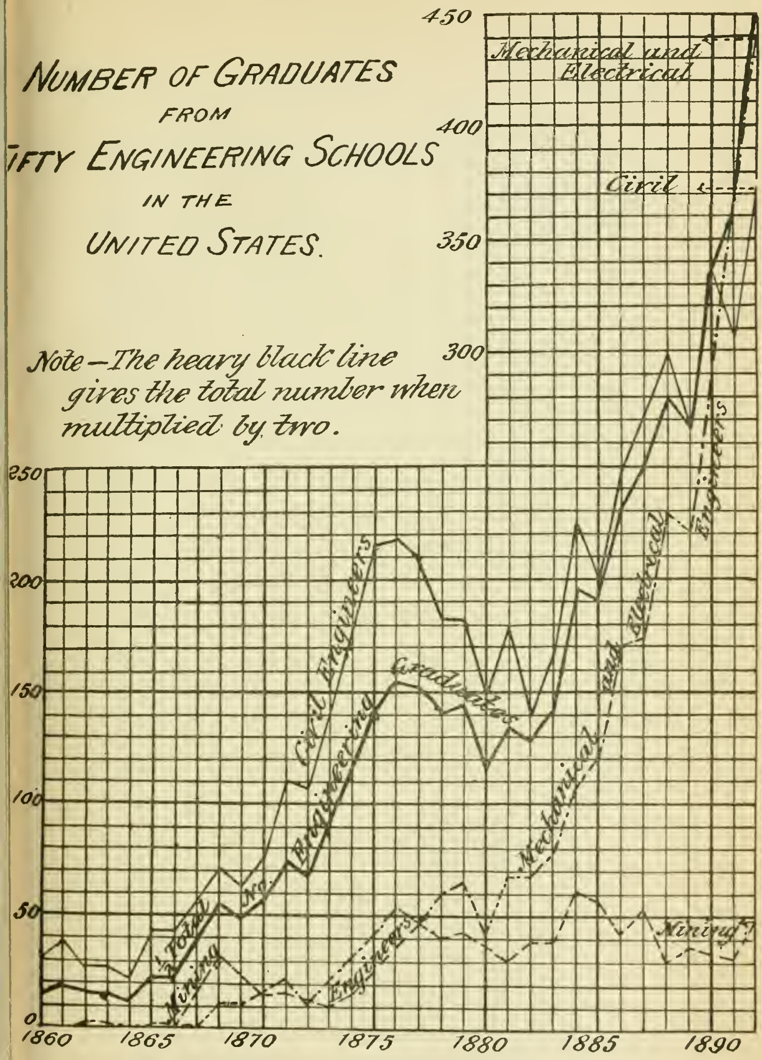
should fairly cover the various lines of work in some one field of engineering practice.

These are, I conceive, some of our most patent embarrassments. But they are all gradually disappearing. There is probably little to be done to remove those from without. We can by making ourselves more worthy of respect and confidence, rapidly rise in the public esteem.

We are now as a profession, I conceive, very much in that uncertain adolescent state in which we all found ourselves when our downy cheeks began to reveal the fact that we were no longer children but when we could not claim to be men. We are sure we are more than mechanics and surveyors, and something different from the mathematicians and the pure scientists, and yet we cannot indicate any clear line of demarcation between ourselves and these other related classes.

As a proof of our approach towards a full grown professional status, however, I wish to call attention to the recent rapid growth of the number of Engineering schools of the United States and the annual number of graduates from the same, as furnishing an astonishingly large amount of suitable material from which to make our ideal engineers, and also to the rapid formation of new Engineering Societies over the country, as indicating a strong and increasing desire for co-operation and association, and as promising a united body of professional workers before many years.

Until after the close of our civil war, or previous to 1866, there were turned out of all the existing engineering schools in this country not more than fifty graduates per year, and these were almost exclusively civil engineers. From that time, and as a result of the great development of our rail-road interests and of the Act of Congress donating the proceeds of the sale of public lands to the several states for the purposes of industrial and technical education, there has been a marvelous growth in the number of Engineering schools and in the number of graduates from them, until in 1892 there were graduated from fifty of the leading schools over 900 incipient engineers in the four lines of Civil, Mechanical, Electrical, and Mining Engineering. All these had taken courses of instruction of four or five years of 9 months each after having passed entrance examinations in the ordinary subjects required in our scientific colleges and universities. This total annual number of Engineering graduates is now increasing at the rate of 150 per year, with no present signs of its decreasing for many years to come. The number of young Engineering graduates now turned out annually in this country may therefore be said to be over one thousand. The accompanying diagram, compiled from the recent series of Articles on Engineering Schools of the United States, in the *Engineering News*, illustrates this growth, and also shows how rapidly the me-



NUMBER OF GRADUATES
FROM
FIFTY ENGINEERING SCHOOLS
IN THE
UNITED STATES.
Note—The heavy black line gives the total number when multiplied by two.
450
400
350
300
250
200
150
100
50
0
1860
1865
1870
1875
1880
1885
1890
Mechanical and Electrical
Civil
Civil Engineers
Graduates
½ Total No. Engineering
Mechanical and Electrical Engineers
Mining Engineers
Mining

THE ENGINEERING SO-

Qualifications for Full Membership.	NAME OF SOCIETY.	Date of Organization,
10 years practice. 5 years in charge.	American Society of Civil Engineers.	1852
	Canadian Society of Civil Engineers.	1887
Competency to assume charge of Engineering Work.	American Soc. of Mechanical Engineers.	1881
	Technical Society of the Pacific Coast.	1884
Practising Engineering with 1 to 5 years' Experience, or Graduate of Engineering School.	American Institute of Mining Engineers.	1871
	American Society of Electrical Engineers.	1884
	Western Society of Engineers.	1869
	Boston Society of Civil Engineers.	1848
	Engineers' Club of St. Louis.	1869
	Engineers' Club of Philadelphia.	1877
	Engineers' Society of W. Pennsylvania.	1880
	Civil Engineers' Club of Cleveland.	1880
	Denver Society of Engineers.	1882
	Engineers' Society of St. Paul.	1883
	Engineers' Club of Minneapolis.	1884
	Engineers' Club of Kansas City.	—
	Montana Society of Civil Engineers.	1887
	Engineers' Club of Cincinnati.	1888
	Engineering Association of the South.	1889
	Wisconsin Polytechnic Society.	1890
	Engrs. and Archts. Club, Louisville, Ky.	1891
	Totals..	....

CIETIES IN AMERICA.

No. of Members in each grade.				Initiation Fee.	Annual Dues.	No. Meetings per year.	Average No. of papers per year.	Estimated Value of the Society Assets.
Members.	Associate Members.	Associates.	Juniors, or Students					
1131	106	70	236	$ 30	$25.00 15.00	20	50	$70,000
287	129	80	187	10	8.00 6.00	16	12	8,000
1273	68	—	211	25	15.00	2	40	85,000
200	—	40	10	5	12.00 6.00	12	12	400
2213	—	185	—	10	10.00	3	800 pp.	20,000
195	448	—	—	5	10.00	10	25	3,000
428	—	—	—	5	10.00 7.50	12	8	2,000
300	—	2	—	10	6.00 4.00	11	18	5,500
180	—	—	—	10	10.00 5.00	18	20	2,000
443	—	15	—	5	10.00 5.00	18	30	8,000
420	—	—	—	none	5.00	20	20	7,000
148	—	7	—	5	8.00	12	16	1,000
70	—	—	—	10	12.00 8.00	25	20	800
45	—	—	—	5	4.00	8	4	500
30	—	—	—	5	5.00	10	6	200
40	—	9	—	5	8.00	9	9	150
50	—	4	—	5	10.00	12	6	400
125	—	3	—	1	5.00 3.00	12	12	100
105	—	2	15	5	8.00 5.00	9	12	250
43	—	—	—	5	10.00	10	6	—
63	—	11	—	10	18.00	12	12	1,200
7789	751	428	659	....	about $110,000	261	468	$215,500

chanical and electrical graduates (which are here combined) are increasing in numbers, while the number of graduates in Mining Engineering remains nearly constant. The number of graduates in Civil Engineering fell off from 1875 to 1883 as a result of the financial panic of 1873, but has since been steadily increasing at the rate of about forty per year. These fifty schools all give fairly thorough courses in Engineering, and probably all that it is wise to try to give in the schools. With a proper apprenticeship in practical work, these young men, if they have the necessary natural endowments, are likely to make creditable members of this new profession. Although many of them will at once fall into other than professional lines, yet it is probable that at least two-thirds of them will make engineering their life work and so become permanent additions to the Engineering profession in America.

My next exhibit is a table showing some of the more interesting data concerning twenty-one of the leading Engineering Societies in this country. This shows that the only societies having severe qualification requirements for membership, are the American Society of Civil Engineers and the Canadian Society of Civil Engineers. Both require ten years practice with five years in responsible charge of work, the American Society requiring a minimum age of 30 years and the Canadian Society of 25 years. In case the candidate has graduated from an engineering school two years less practice is demanded. In this particular the graduates are not credited with as much relative advantage as they deserve, for certainly as a preparation for a high grade professional practice, a regular course of study in a good engineering school signifies a great deal more than two years of practice in some subordinate position. (See pages 84, 85.)

Two other societies are put down as requiring competency to take responsible charge of engineering work, and five years of professional experience, these being the American Society of Mechanical Engineers and the Technical Society of the Pacific Coast.

The other societies are more or less lax in their requirements, a simple graduation from an Engineering school or actually practising Engineering in some creditable capacity usually admitting to membership.

It will be noted that the total full membership of these twenty-one societies is 7494, while the total membership in all grades is over 9,000. If allowance be made for duplicate memberships in two or more societies, it is likely that there are about 7,000 different persons making up the membership of these societies.

The annual contributions in the form of annual dues, which they pay to sustain these professional organizations is over 100,000 dollars, and their estimated total assets is over $200,000. There are a number

of new and smaller societies besides those listed in this table, which are strictly professional bodies, but which are as yet of no great importance numerically.

From this showing from the side of the Engineering schools on the one hand and of the Professional societies on the other, it is evident that the Engineering profession in America is in a state of rapid development, equalled only by the development of our natural resources.

What it will come to be in the next quarter or half century it is now impossible to predict or even dimly to imagine. This, however, we know, that the profession is now founded on the most practical and thorough technical training to be found in any country, and its members are coming to feel alive to the necessity of co-operation and of mutual support. Out of this there must soon grow a high standard of professional etiquette and ethics, as well as of service performed, and with these will come that recognition from the community and that high regard in the estimation of our fellow countrymen which every man of character and ability hopes to attain unto, and which he values next to his own self-respect.

CROSS TIES FOR RAILWAY BRIDGES.

By James Ritchie, Member Civil Engineer's Club of Cleveland.

[Read December 13, 1892.]

In Cooper's Specifications of 1890, pages 2 and 3, we find the following:—"The distance between cross ties on bridges shall not exceed six inches," and "the maximum strain allowed upon the extreme fibres of the best yellow pine or white oak floor timbers will be 800 lbs. per square inch;—the weight of a single engine wheel being assumed as distributed over three ties spaced" as above.

The weights of engine wheels given in the same specifications are 20,000 lbs. on the Lehigh heavy engine and 25,000 lbs. on the eight wheel engine. The writer is informed that the C. C. C. & St. L. Ry., have several new 10 wheel engines which have *actually* 39,000 lbs. on each pair of driving wheels spaced about 6 ft. apart, or 19,500 lbs. every six feet on each wheel. The Lehigh heavy grade of Cooper has its 20,000 lbs. spaced 4′ 6″, and the eight wheel engine referred to above has its 25,000 lbs. spaced seven feet apart.

The following table is computed from the engine wheel load of 25,000 lbs. distributed over three ties, that is 8,333 lbs. per tie. To this is added 25 per cent. for the effect of impact making the load about 10,416 lbs. per tie.

The spacing of the track stringers is made 6′ 6″, 7′ 0″, 8′ 0″ and 9′ 0″ and the fibre strains for 8″ × 6″, 8″ × 8″, 8″ × 10″, 10″ × 10″, and 10″ × 12″ ties, deduced from above loads are shown in the table.

SIZE OF TIE.			CALCULATED FIBRE STRAIN.			
Width.		Depth.	Stringers 6′ 6″	Stringers 7′ 0″	Stringers 8′ 0″	Stringers 9′ 0″
8″	×	6″	1960	2604	——	——
8″	×	8″	1098	1500	2208	——
8″	×	10″	702	937	1407	1875
10″	×	10″	——	750	1125	1500
10″	×	12″	——	——	780	1040

For calculating the bending moment for above results a lever arm was used equal to the distance from center of rail to center of nearest track stringers.

The present practice on many railroads is to use 8″ × 8″ ties with 6′ 6″ spacing of track stringers. This gives a fibre strain of 1098 lbs. per sq. inch, which is not excessive in consideration of the fact that we have added 25 per cent. to the actual loads. It is not stated in Coopers Specifications whether the 800 lbs. fibre strain allowed by him, is made that amount to include impact or whether we are to add to the loading as is done above. It appears to the writer that 800 lbs. fibre strain is very small unless the allowance for impact is included, as he has used 1,000 lbs. and as high as 1,200 lbs. per sq. inch on best white oak.

The question of the actual distribution of the engine loads over the ties is a very interesting one but it seems not capable of accurate solution. The determination of the rigidity and the deflection of the rail connecting the ties is a problem of the greatest difficulty, when we consider that the said rail is a continuous girder and the ties are its supports, none of the latter being on the same level under the moving load. It is claimed that the spacing of the stringers further apart than 6′ 6″ is an advantage, as by the probable greater deflection of the tie in this case, we shall distribute our wheel load more uniformly and relieve the track stringer of a portion of the effect of impact. For a spacing of 7′ 0″ we should use not less than 8″ × 10″, for 8′ 0″ not less than 10″ × 10″ and for 9′ 0″ not less than 10″ × 12″ ties.

By using 10″ × 10″ ties, 8″ × 8″ guard timbers, and 80 lb. steel

rail we have a floor weighing 385 lbs. per lineal foot of track, or about 15 lbs. less than the usually assumed dead load of floor.

The writer does not know of an instance in which a bridge tie has failed by breaking under the load, and does not think there is danger in that direction on account of the margin in the so-called factor of safety.

The spacing of 6″ required by Cooper should not be increased but rather should be decreased to 4″. Many of the closely spaced floors have saved wrecks by preventing, with the help of the timber guards, the bunching of the ties. The writer would use 8″ × 8″ guard timbers notched one inch at each tie, and bolted to every other tie, and does not consider any additional interior guards of advantage, unless they are sufficienlty far away from the rail to permit the wheels to run between the rail and the guards.

It is suggested that experiments be made to determine the actual deflection, co-efficient of elasticity and from them deduce the actual fibre strain in various sizes of bridge ties, and the writer intends to do so at some future time.

DISCUSSION.

Mr. Osborne :—Mr. President, I have the pleasure of presenting a very complete and valuable discussion by Mr. Robert Gillham, of the Engineers' Club of Kansas City.

Mr. Robert Gillham, C. E.

I have been much interested in the discussion of cross-ties as used on almost all kinds of iron and steel structures.

I have for many years been impressed with the view that cross-ties on bridges, viaducts and elevated railways could be dispensed with and the structures made to serve their purpose better without them than with them. Cross-ties cannot be considered an element of strength in any structure and must be treated as a dead load, for which provision must be made in determining the strength of the structure. If ties can be dispensed with the structures can be proportionately lessened in weight, depending in some respects upon the details adopted in designing the structure, in order to meet the condition brought about by their abandonment.

It is true that members could be substituted and details adopted that would result in a marked increase in metal in the structure, but good designing and good details will not result in an increase but rather in a decrease in weight of structural parts as compared with those having cross-ties. There are structures, however, where this would not apply. Independent of the question of decrease in weight,

which, after all, may not be as important to some engineers as to others, a better and more modern design is secured by the elimination of the ties.

In the case of elevated railways every argument seems to be in favor of the omission of ties. In considering the question in designing the elevated railway for Kansas City, Missouri, it was the opinion of the Edgemoor Bridge Company and the writer, that if a design could be secured that would embrace all the requirements of strength, and meet all the conditions of erection and use, which at the same time would not require the use of the ordinary wood cross-tie, it would result in securing a higher type of modern elevated railway construction.

No one can question the serious objections offered against the New York type of elevated railways, where cross-ties are used. These ties are the principal cause of darkening the streets through which the roads are built. We must admit, in many sections of the New York roads the light is so generally excluded by these ties that no reasonable person can question the damage resulting to property along these streets.

Having in mind the objectionable features of roads having cross-ties the writer made an effort, in building the Kansas City Elevated Railway, to eliminate them, resulting in the designing and erection of a very acceptable structure without cross-ties.

The small photograph and sketches submitted, to some extent illustrate the track and chord construction of the road. The details have, after five years of actual use, proven satisfactory. The train load consists of an engine of 30,000 pounds and two coaches of 24,000 pounds each, loaded.

No objection has been offered against the structure by property owners on account of the exclusion of light, the result in this respect is very satisfactory.

The noise due to the passage of trains is very much less on this structure than on the New York structure. Wood cross-ties to some extent tend to enhance the vibrations and sound due to the passage of trains. With these excessive sounds due to train action, and the exclusion of light to a marked degree, an elevated railway cannot be classed with the higher types of structural design. It is true that the question of light does not apply to bridge construction, and noise is not a serious matter, but cross-ties weigh as much on a bridge as on an elevated railway, and are not an element of strength, but become a dead load that must be provided for. The details developed for one class of structures can very often be applied, with slight modifications, to others.

The designs and details used for the support of wheel rails in an ele-

vated railway will, with slight modifications, apply to railway bridge construction.

It is asserted by not a few engineers that a pin connected truss in elevated railway construction is not as desirable as riveted plate girder designs. We will not now discuss this question. In the case of the Kansas City Elevated Railway we have a structure composed of a series of pin connected trusses, having no wood cross-ties for rail supports. The trusses average about forty-eight feet span. Each rail is supported by a truss, and the trusses forming the single track are tied together by brace frames and wrought iron angle ties. The trusses are supported by cross girders, which in turn rest on columns. The upper chord of each of the trusses is made from two ten-inch channel bars, arranged parallel to each other and eight inches between faces of channels. The channels are tied together by means of *U* steel plates, riveted to web or face of channel, sixteen inches apart. At each panel point in the truss additional plates are riveted between the *U* plates and face of channel, which plates extend below the lower side of the channel bars a sufficient distance to allow the making of pin-holes through these plates. Two or more web members of the truss meet at the pins inserted through the plates referred to.

It will be seen, that, between the two channel bars, held together by means of the *U* plates, there is a space of eight inches, in which space the wheel rail is placed resting on the *U* plates, and fastened by bolts to the same. On the top of each *U* plate and directly under the wheel rail is arranged an oak block about one and one-half inches thick, having the same width as the *U* plates. These blocks of wood serve to cushion the rail and assist materially in lessening the noise. The rails move under the bolts by contraction and expansion, independent entirely of the structure. The upper edge of the channel bars of the truss are considerably higher than the top of the wheel rail, and thus we secure an efficient and satisfactory guard rail. The structure has given entire satisfaction.

It will be of interest to consider a comparative statement of the relative weight and cost per lin. foot of the structures with and without cross-ties:

Length of span, 48 feet.
Width, 20.5 feet.
Height of Truss, 5 feet.
Moving Load, 24,000 pound Steam Motor,
Followed by 14,000 pound Passenger Cars.
Cost estimated at 5 cents per lb. erected.

PLATE GIRDER DESIGN, ONE SPAN.

Wrought Iron, 24,300 lbs. at 5 cents.................$1,215 00

Cross-ties and Guard-rails	108 00
Total	$1,323 00
Cost per lin. foot	27 56

LATTICE GIRDER DESIGN, ONE SPAN.

Wrought Iron, 22,700 lbs. at 5 cents	$1.135 00
Cross-ties and Guard-rails	162 24
Total	$1,297 24
Cost per lin. foot	27 02

TRUSS GIRDER, ONE SPAN, WITHOUT CROSS-TIES.

Wrought Iron, 19,079 lbs. at 5 cents	$953 95
Cost per lin. foot	19 87

These three designs were made in keeping with a carefully drawn specification, and were competitive designs.

A Lattice design could be made that would require less iron than the one above, but would not possess the high merit found in the Lattice Girder referred to, and at the same time meet the requirements of the specification.

Weight per lin. foot of the structure :

Truss Girder, without cross-ties, 398 lbs. per lin. foot.

Lattice Girder, with cross-ties and guard-rails, 470 lbs. per lin. foot.

Plate Girder, with cross-ties and guard-rails, 511 lbs. per lin. foot.

It will be understood that the difference in cost and weight is not entirely due to the absence of cross-ties, but is due to designing a structure to meet the conditions brought about by the absence of ties.

All structures used for railway purposes, to my mind, are much higher types of structures if the heavy wood cross-ties and wood guard-rails are omitted. I think the same conclusion is maintained by many engineers, when the question relates to elevated railways, who may have a more conservative opinion when the question relates to bridges.

The question of maintenance is of some importance, and the cost of renewals should also receive consideration.

MR. OSBORNE : The limit in Mr. Cooper's specifications is 800 pounds per square inch. Mr. Thacher allows 800 pounds on spruce and cypress, 1,000 pounds on white pine and hemlock and 1,200 pounds on yellow pine and white oak. Practice, in general, seems to be to use from 1,000 to 1,500 pounds per square inch, depending on quality of timber and conditions of loading. The United States Government has allowed, in some structures, a unit strain of about 2,200 pounds to the square inch. This strain, however, would only be produced by the passage of a very heavy road roller, and would be very seldom, if ever, applied. For ordinary highway bridges I do not think 1,500 or 1,600

pounds at all excessive. Railroad cross-ties are, however, different things ; they are fully loaded at every passage of a train, and, not only that, but they have the load suddenly applied and suddenly released a number of times during the passage of each car, and the effect of this must be quite injurious.

The President : Probably what Mr. Ritchie added to the strain would be produced by ordinary traffic. It is possible that Cooper selected 800 pounds and included impact in that, so as to obviate allowing anything for impact.

Mr. Herman : Mr. President, I would like to know if there are any experiments on record in regard to impact on cross-ties or anything. Is anything known on the subject ?

Mr. Osborne : Where you consider the measurement of deflection, a great many tests of that kind have been made on new bridges, passing the train from 30 to 40 miles an hour, and then measuring the deflection with the load standing on it. Sometimes they show a greater deflection under a moving train ; sometimes more deflection under a train standing still. I have never been able to discover that the train makes a difference.

Mr. Herman : The reason may be that the impact in a moving train is not represented by speed, but by the number of revolutions made by the engine. There are other facts which would produce these various effects. I had, myself, occasion to measure the effect of moving locomotives or trains over bridges, and I got some of the most peculiar results, which could not be tabulated ; they were complicated conditions. What I mean, is there anywhere a record of impact or stress, on any structure, the result of impact? I have not succeeded in finding any such records.

The President : I understand that you mean impact from some force other than the moving train.

Mr. Herman : Yes, from a falling body or a hammer, or a weight, or something else.

Mr. Searles : It occurs to me to say that probably no train rolling over a bridge could be said to produce impact upon that bridge as a whole. Nevertheless, as the weight passes upon the new panel bars, that panel may receive a shock something like impact ; therefore, my idea has been that the result of impact is likely to affect the bars, rather than the bridge as a whole.

An engine rolling upon a new set of cross-ties may produce impact on them, and yet we would hardly call it impact on the whole structure. The structure, as a whole, receives its load gradually, and each successive tie receives it suddenly, modified by the stiffness of the rail above. This question is a pertinent one ; if Cooper has not so stated he

should have done so. He should not leave the profession in doubt as to whether or not impact is included in his calculations.

Mr. Ritchie : Mr. President, I should like to know whether any one has ever figured, accurately, the distribution of loads on a tie. Cooper says it is assumed to be distributed over three ties ; but he don't give any figures for it.

The President : I don't recollect having seen any account of any attempt being made to compute what the strain on different ties would be where they are put together. I am very much in doubt whether much is distributed more than one way. My observation is that two carry the load, but it would require so much larger ties than the average purchaser is willing to pay for, so it is concentrated, in practice, on three ties. I hardly think that, in case the load being over one tie, that the one 10 or 12 inches from it would receive very much of a load unless the one immediately under the load was considerably deflected. The rail is not very rigid when it is placed on bearings two feet apart. These deflections should be small. In most of our structures nowadays, impact is not estimated only on comparatively few bars, and those are the ones that are especially liable to the single loading only.

In regard to the stringers that Mr. Ritchie speaks about. I suppose when Cooper made his specifications he had the space of the cross-ties in mind. In many cases cross-ties are not spaced, but the fibre strain on the wood is specified so the design will not exceed the limit given in the specifications. I haven't the latest edition of Cooper's Specifications ; the latest I have were published in 1891. In many specifications the spacing of the stringers is left to the designer. The stringers are spaced for not to exceed 5 or 6 feet apart, sometimes with outside stringers occasionally wood, sometimes iron. This method used to be quite common, the outside stringers taking one-half as much strain as the stringer immediately under the rail. I presume that is what Cooper had reference to, but he didn't state it.

Mr. Ritchie: The paragraph I referred to was simply spacing of the cross-ties 6 inches apart, not the spacing of the stringers. I took the spacing of the stringers three different spaces : 6′ 6″, 7′ and 8′.

The President : I think he left that matter of spacing the stringers for the very purpose that the stringers should be spaced dependent upon the cross-ties, so the fibre strain should not exceed 800 pounds.

Mr. Ritchie : The further apart the stringers are the more deflection we have in cross-ties, consequently the more the cross-ties act as a cushion for reducing the impact across the bridge.

The President : I expect the stringers are spaced about 6½ or 7 feet apart.

ENGINEERING CONGRESS AND ENGINEERING HEADQUARTERS, COLUMBIAN EXPOSITION, 1893.

ADDRESS BY MR. O. CHANUTE, AT ANNUAL MEETING, WESTERN SOCIETY OF ENGINEERS.

[January 4, 1893.]

Gentlemen of the Western Society: You have before you this year a pleasing and an arduous task. As the hour is well advanced, and you all desire to hear the speaker who is to follow, I shall make but a few brief and plain statements of what has been accomplished up to the present time, and what it behooves the members of this society to be prepared to do during the coming summer.

As our incoming President has told you, the project for an International Engineering Congress, to be held during the World's Exposition, was first originated in this society about two years ago, by our Past President Mr. Corthell. Shortly afterwards he went to Europe, and while there took occasion to confer with Engineers in various countries concerning the project. We found that they manifested so great and so growing an interest in this proposed Engineering Congress, that it was soon seen that it would be impracticable to arrange and manage it through a single committee in Chicago, and that the aid of Engineers from all over this country must be enlisted.

Circulars were accordingly issued to the various engineering societies and some 16 of them have formed a temporary association for the purpose of planning this Congress, and of maintaining joint head-quarters during the Exposition, concerning which latter project, I will say more hereafter.

The Executive Committee of this temporary association, whose duty it became to plan how this Congress should be organized, soon found that in order to survey, even approximately, the field of modern engineering, it would be necessary to divide the congress into seven sections, and to entrust the organization and management of each of those Divisions, either to a National Society, or to some representative of a governmental department.

As finally arranged the Divisions are as follows:

DIVISION A.—Civil Engineering in charge of the American Society of Civil Engineers. Address F. Collingwood, Secretary, 127 East Twenty-third street, New York, N. Y.

DIVISION B.—Mechanical Engineering, in charge of the American Society of Mechanical Engineers. Address F. R. Hutton, Secretary, 12 West Thirty-first street, New York, N. Y.

DIVISION C.—Mining Engineering in charge of the American Institute of Mining Engineers. Address R. W. Raymond, Secretary, 13 Burling Slip, New York, N. Y.

DIVISION D.—Metallurgical Engineering, in charge of the American Institute of Mining Engineers. Address R. W. Raymond, Secretary, 13 Burling Slip, New York, N. Y.

DIVISION E.—Engineering Education, in charge of a special committee appointed by President Bonney. Address Prof. I. O. Baker, Chairman, University of Illinois, Champaign, Ill.

DIVISION F.—Military Engineering, in charge of Major Clifton Comly, U. S. A., representing the United States War Department at the Columbian Exposition. Address Major Clifton Comly, Governor's Island, New York Harbor, N. Y.

DIVISION G.—Marine and Naval Engineering, in charge of Commodore George W. Melville, Engineer in Chief, United States Navy. Address Com. Geo. W. Melville, Eng. in Chief, U. S. N., Washington, D. C.

These Societies and gentlemen have all entered upon the work of preparation and correspondence and they all report that there is every prospect that the Congress will be a great success. It is to be held by each of the National Engineering Societies in lieu of their usual summer meeting or convention, and the interest manifested not only in this country, but abroad, by Engineers, seems to promise a large attendance.

This Congress is to be held during the week beginning on the 31st. of July, and ending on the 6th. of August, and is to take place in the Art Palace on the Lake Front. It is to be inaugurated by a General Session, after which the Divisional Sessions will be organized and controlled by the officers in charge of the Divisions.

The proceedings are to consist in the reading of specially prepared papers, which are chiefly being obtained by solicitation, and the more important of which are to be printed in advance, and presented only by abstract, so that their discussion by the experts best equipped to speak on the subject may follow without loss of time. The object being to elicit the latest and soundest information concerning the constructions, the machines, the processes and the investigations which come within the province of the modern Engineer.

It is understood that each Division has already secured the promise of 20 or 30 papers, some of them of very great and permanent interest, and that the prospects are that more will be offered than can be prop-

erly considered during the six days at command, but in any event we may be sure that there will be no lack of value and variety in the proceedings and we may fairly hope to receive the very latest and best information concerning the science of Engineering in its broadest sense.

Now as to the Engineering headquarters. The prospect being that a large number of Engineers will come to Chicago this year, not only to attend the Engineers Congress but to see the Exposition, it seemed to be desirable that they should provide one or more rallying points where they could meet each other, obtain information, and also receive such of their foreign brethren as may come to this country. For this purpose, the 16 Engineering Societies of the United States and Canada, (for in an Engineering sense we consider the Canadians as part of ourselves) decided that it would be advisable to maintain for themselves and their visitors Engineering headquarters in Chicago during the entire 6 months of the Exposition.

Funds have been raised, and an organization effected for that purpose, and this organization has secured accommodations at two points. First a suite of rooms, which are to be occupied from May 1st., at No. 10 Van Buren St., in the building which was formerly part of the Art Institute, and which is now in the possession of the Chicago Club, being within a stone's throw of the Art Palace in which the Congress is to be held, and second a room kindly placed at our disposal in the Mining Building at the Exposition.

It is proposed to maintain a staff, representing the Engineering Societies, at both these points.

The staff at No. 10 Van Buren St., (where, by the way, the space consists of five rooms, two of them 25 × 50 ft. and the others about 20 ft. square), will probably consist of a Secretary, one or more clerks, a Stenographer and an Interpreter. Its duties will be to receive the visiting Engineers, to give them such information as they may desire, to make them acquainted with each other, as well as with such other persons as they may wish to meet, and generally, not only to further in every way such Engineering investigations as they may be engaged upon, but to make them welcome in every way to these quasi clubrooms and to the City of Chicago.

The duties of the staff at the Exposition, which will probably consist of two or three employes, will consist in furnishing to visiting Engineers information concerning the location and character of Exhibits pertaining to the specialty which they may desire to study. Practically therefore these employes are expected to serve as reference guides, and those among you who have seen the amazing immensity of a modern International exhibition, will appreciate how usful in saving time such guides can be, by pointing out where the scattered exhibits, pertaining to even a single technical subject, are to be found.

It has also been suggested that experts in various branches of Engineering might be induced to deliver occasional peripatetic discourses upon their specialties, similar to the weekly "promenade visits" to the Paris Exposition, organized by the French management, in which a number of Engineers led their fellow members to such exhibits as pertained to the particular subject selected for illustration, keeping up the while a running commentary upon what patent experts call "the state of the art." Such quasi-lectures, and such guidance through the Exposition would be, as you will readily perceive, most valuable and instructive, but in order to carry them out we shall need, from the members of this Society, all the support and all the co-operation which they can furnish.

We have already issued, in the name of the associated American Societies invitations to the various leading Engineering Societies abroad to accredit their visiting members to these proposed headquarters so that they may avail fully and freely of such facilities as we are providing for ourselves. Some 30 such invitations have been sent out, more will follow, and when our foreign visitors press the button we must be ready to:— go to the front door.

Such European Engineers as may come over in a body, or rather, all they can capture will be taken in hand by the Eastern Societies, who will facilitate their visits to such points of Engineering interest as they may desire to see in the intervening country, show them proper attention, and then turn them over to us.

When they reach here it will be our pleasant duty to entertain them and to forward their wishes, but even with the aid of all the members of this Society I feel that it will be most difficult to return the magnificent hospitalities which were extended to the American Engineers who visited Europe in 1889. They were shown by their entertainers, not only all that was interesting from a professional point of view, but they were overwhelmed with personal and social attentions, which our utmost good will may find it impossible to imitate.

We must however do the best we can, and the members of the Western Society of Engineers, will doubtless hold themselves in readiness at all times during the Exposition, to meet such of their professional brethren as shall visit the city, to furnish them information and to pay them social attention, to attend little impromptu receptions when leading Engineers are in the city to assist in guiding our visitors through the Exposition, either with or without peripatetic discourse, and generally to hold themselves in readiness to assist the organization which they were the first to propose, and which now represents some 7000 members, so that we shall all be still prouder of our title as members of the Western Society of Engineers.

CHARACTER IN THE ENGINEERING PROFESSION.

EXTRACT FROM ADDRESS OF RETIRING PRESIDENT, ISHAM RANDOLPH, WESTERN SOCIETY OF ENGINEERS.

[Delivered January 4, 1893,]

In constructive engineering, during the year 1892, although much has been done, few works in America have risen to a dignity commending national attention. With the most conspicuous of these our own members have been associated in a distinguished manner. The Mississippi, "father of waters," makes a rift in our continent, which commences not far from British territory, and works southward through sinuous convolutions more than three thousand miles to the gulf. Beginning at Brainerd, in the far north, the ever-widening stream is spanned, time and again, by railroad and highway bridges, until the Eads structure is reached at St. Louis. Between that and the Gulf, for many years, the only communication between its opposite shores was by marine conveyance, but now there is another noble structure, connecting Tennessee and Arkansas, at Memphis. This majestic structure adds one more notable achievement to the record of our distinguished member, George S. Morison.

On the 3d of September a notable event transpired in the Desplaines Valley, near the classic village of Romeo. Ground was officially broken and rocks rent by the official discharge of an electrical battery, for the great combined drainage channel and ship canal, which is to restore that connection between the great lakes and the Gulf of Mexico which, those who read earth's history, as recorded in the book of geology, tell us existed long before there was any other method devised for keeping the chronicle of great events. To make this event possible, our past president, L. E. Cooley, has given up his best years to ceaseless research, ill-requited labor, and often brutal criticism. Never was there a more notable example of what one persistent man can do to mould public sentiment and force legislative action. As the chief engineering executive of this great enterprise, we recognize another of our past presidents and most valued members. During this year, as if by magic, vast and magnificent structures have reared their majestic proportions within the domain of the people of Chicago, known as Jackson Park. Civil engineers have supplied the grand arches and ribs of steel, which made it possible thus to excel in vastness every building enterprise which earth in its unnumbered centuries

has borne upon its bosom; and architects have taken these giant skeletons and covered and veneered them with counterfeited marbles in dignified and fair proportions, until the work of these brother craftsmen strikes wonder, admiration and awe into the hearts of all beholders.

The night is wearing on and I must yield the floor to others, but not until I have addressed myself to the young men of our organization. The forceful, hopeful, earnest contingent, who strain the eyes of imagination dipping "into the future, far as human eye can see," striving to draw aside the curtain which hides "the vision of the world and the wonder that shall be." Young men, I feel as if I had a right to speak to you, because my sympathies are so strongly with you, and because it seems but yesterday that I, too, was young; but on from the yesterday of my youth the resistless force, which drives the flying chariot of time, has forced me to the past meridian of life. And from that vantage ground I speak to you to-night. You have joined battle with the forces of the world, you stand shoulder to shoulder with the men who are grappling with the raw materials of the universe and moulding and shaping and framing them to fit the multiform needs and uses of earth's myriad inhabitants. Some of you come armed cap-a-pie for the contest, others face the battle with an equipment but little better than the shepherd's sling and the few smooth stones from the brook. To the one class I would say, be not too confident. To the other, be not cast down by the scantiness of your preparation.

In what I am about to say I would not be understood, for one moment, to underrate the value, the vast advantage of a thorough scientific and liberal education. Few men have coveted more earnestly than I the possession of just such an education, and few have attained worthy results with more labor than it has fallen to my lot to endure in prosecuting my life's work, because I lacked this equipment for its duties.

The first essential to success in life is the possession of a sound mind: and what is not possible to him who has a sound mind domiciled in a sound body, with a strong will to urge both to highest effort? Taken two such men, with equal natural powers, and equip one with a thorough knowledge of the laws of nature and the best methods of turning the forces of nature to account in the work which lies before him ere he can reach the goal of success. Then let both men choose the same goal, will not the man who knows how, reach it long before the man who has to learn how? But the last man will get there if no infirmity of purpose overtakes him. Then again, take two men, one with a natural gift for certain lines of work or research, and the other with no such gift, but with years of training and discipline to fit him for the work, and the race will not be so unequal as in the first case;

when the one reaches the goal the other will not be far behind him, and it is a question which will reach it first. The schools, colleges and universities, which stand like storehouses of knowledge all over the land, have a mission to mankind which is helpful and ennobling. But whence came our engineers before these temples of learning were reared? What faculty graduated John B. Jervis? Did Benjamin H. Latrobe pass from classic shades to the fields and forests, the rugged mountains and the brawling torrents, where he exercised that skill which gave him his great name? What of Roswell B. Mason, was he a graduate? E. S. Chesbrough left monuments behind him which made him famous on two continents for his constructive genius while he lived, but can his descendants point proudly to their father's diploma? How many years was James B. Eads coached by professors before he built that gunboat fleet or flung those ribs of steel across the Mississippi, or planted the jetties at its mouth or conceived the idea of the ship railway? What college trained Thomas U. Walter, between the time of his dropping his bricklayer's trowel and his building the capitol of this nation?

I might go on and on, but these proud names will suffice to show that while knowledge is power, it is not all pre-empted by the schools. Take heed then, you young men, who oftentimes feel cast down by the odds you think you see against you. If you have a genuine love for the work, which is the daily lot of the engineer, devote yourselves to it. and remember that you have more help than the men before you, who, single-handed and alone, wrought out of their inner consciousness the means by which they attained their ends. And now to those of you who have the equipment of varied knowledge, learn to handle it aright, and because you know so much, do not fall into the error of believing that you know it all. The man who reaches that conclusion will not go far before he overtakes confusion and disaster. I have had men under me by whose knowledge I was fairly appalled. They were walking encyclopedias, versed in sines that failed not to the tenth decimal, but so constantly flying off at tangents that they became eccentric to a degree which destroyed their mental balance and they could not be trusted to do common-place every-day work that pertains to our duties without having an *ignoramus* along to keep them straight. You who have this splendid equipment, learn to use it so that it may be effective. Watch the *practical men*, see where they fail for want of what you possess. Harness your theories for the every-day work of life, and if they are true your work will be the better for their aid; but if false, you will soon demonstrate the fact, and lean upon the true and cast away the fallacious. As I look upon you all, I read in your faces the laudable ambition to reach success. What is success? How many standards are there? Some unthinking or sordid listener

might reply the accumulation of vast wealth—that is success. Others again will say the attainment of power and position is the goal of our desires. And still others will ask for a good name, with the ability to owe no man anything, and the calm consciousness that in the attainment of these they had wronged no man.

He who gauges success in our profession by the money standard has a low conception, indeed, of the full import of the term. Judged by the measure of accumulated gains the lives of ninety per cent of the men whose names shine upon the pages of human endeavor have been flat failures. One of our humorists, I think, we must credit it to Josh Billings, has said: "It is easy to see what the Lord thinks of money by the people he gives it to." True success is impossible apart from probity and honor, and it is a fact, which must not be lost sight of, that the men who by their ability and skill have placed the engineering profession upon the high plane it occupies to-day have been men of exalted characters. And how are characters built up? Can a fabric of truth rest upon an aggregation of lies? Does honor rear its head above a stagnant pool of immorality? Does integrity come forth from a heart full of dishonest intention? No, my friends, you can no more rear a noble character upon a foundation of unstable or corrupt morals than you could sustain the Auditorium upon the muck and slime of a morass. There is not a man here to-night who has attained to responsible position who cannot revert in thought to not one, but several, men, with whom his professional life has brought him in contact, whose failures, utter and complete, were traceable to the absence of character. I have known and loved and yearned over such men as these. I have had comrades who were manly and generous and gentlemanly, gifted by nature with mental ability and reinforced by the schools, but lacking in some vital element of character. In their training the item of self-control had been left out, passions and appetites dominated their lives, or indolent self-indulgence stayed their hands from every effort worthy of their ability. In offices throughout our land such men as these are ekeing out miserable existences, cursing fate for their ill luck, and drifting on helplessly and hopelessly into the oblivion which will whelm them at last. Young men, aim high in all things, but aim highest of all in character. And now, the king is dead, but his disembodied spirit hovers near to wish the king a successful, a beneficent and a glorious reign.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

BOSTON SOCIETY OF CIVIL ENGINEERS.

JANUARY 25, 1893. A regular meeting of the Society was held at its rooms, 36 Bromfield street, Boston, at 7:40 o'clock, P. M.

President Henry Manley in the chair. Thirty-seven members and visitors present.

The record of the last meeting was read and approved.

Messrs. George H. Hall, Jr., and Edward D. Treadwell were elected members of the Society.

A committee consisting of Geo. S. Rice, L. M. Hastings, J. L. Woodfall, E. S. Davis and J. H. Stanwood were chosen to nominate officers for the ensuing year.

On motion of Mr. Howe, the thanks of the Society were extended to Major W. R. Livermore, Engineer Corps, U. S. A., for the courtesies shown the members on the occasion of the visit to the light-houses in Boston Harbor.

The Secretary read a communication from Mr. Thomas Appleton, the Society's representative on the General Committee, Engineering Congress, giving the latest information in regard to the preparation for the Congress. The communication was placed on file.

The President was appointed a committee with full powers to make the necessary arrangements for the 11th. Annual Dinner.

On motion of Mr. Hodgdon, the sum of $75 was appropriated for subscriptions to periodicals, binding and other expenses of the Library.

The President then introduced Mr. John C. Trautwine, Jr., of Philadelphia, who spoke substantially as follows:

Mr. President and Gentlemen: It is with very especial pleasure that I appear here this evening as the guest of the Boston Society of Civil Engineers. So far as I can recollect, all my associations with Boston have been pleasurable, and pleasurable only. Even in my childhood days, the name of Boston called up instinctively to me a place of peculiar charm; so that when I made my first visit to your city, a little over a fifth of a century ago, it was something of a disillusion to find the laws of gravitation prevailing here, the atmospheric pressure about as usual and its inhabitants, while I have no fault whatever to find with them,—quite the contrary,—still very much flesh and blood like some of the rest of us.

Some years later I had the pleasure of a little visit here, when Prof. Vose kindly showed me over your sewerage works, and we made a trip to the out-fall, in company with Mr. Fteley, now of New York. About the same time I had the pleasure of a visit from your Mr. Brooks, at my home in Philadelphia. Mr. Brooks then endeavored to impress me even more fully than I was then already impressed, with the importance and advantages of the Metric system, a service for which I have always felt specially indebted to him. Then I must not forget that in Paris, two or three years ago, I had the pleasure of sharing, with other engineers from this side, in the hospitalities of the French Society of Civil Engineers, represented by your Mr. Woods.

But no single act has done more to endear Boston to me and to make me

feel at home here than the action of the Boston members of the American Society of Civil Engineers, a couple of years ago, when I had been reluctantly made a rather prominent figure in an electoral contest in New York; and when, as I understand, the members here of that Society met together and agreed to support my candidacy on that occasion. I refer now, not to the fact that their action at that time tempered the severity of the abrupt fall which I then suffered, and rendered my defeat less overwhelming, than it otherwise would have been. I refer rather to the moral support which that action gave me. I have found that in this world there are quite enough things to keep a man in humble conceit of himself, no matter how earnestly he may strive to think himself of some account; and it is no small matter to be assured of the confidence of a body of men of such standing. I am glad of the opportunity of thanking such members of that body as may be here for their faith in me, as manifested by their action at that time.

And now, coming here as your guest, I have added to the pleasant associations I have with your city, in the very agreeable and instructive trip that we enjoyed this afternoon. My only regret is that not being a member of your Society I could not join in the vote of thanks to the Major here for the courtesies shown us on that occasion. (Applause.)

Mr. Edward P. Adams presented the paper of the evening, describing the Light-house System of the United States. The paper covered in a very comprehensive manner the history and theory of lighting our coast, and the present organization of the system.

The reading of the paper was followed by a short discussion on the subject of the paper by Major W. R. Livermore, Engineer Corps, U. S. A., Light-house Engineer of the First and Second Districts.

(Adjourned.) S. E. TINKHAM, Secretary.

WESTERN SOCIETY OF ENGINEERS.

299TH. MEETING, FEBRUARY 1ST., 1893. The 299th. meeting of the Society was held at the rooms of the Central Traffic Association, The Rookery, on Wednesday, February 1, 1893, at 8 p. m. President Robert W. Hunt in the chair and some 40 members and guests present.

The minutes of the last meeting having been printed and distributed, the President suggested that in accordance with custom the reading be dispensed with except as regarded the Financial Report which had been promised and which he would now call upon the Secretary to read.

After the reading of the report the President requested the Secretary to read the following resolution passed by the Board of Directors:

Resolved: That the sense of the Society be taken upon the financial policy to be adopted for the future, and that the suggestion be made that a committee be appointed to formulate such financial policy, and also to formulate a plan for raising monies for extra expenses of the Society during this year.

The President hoped the Society would act upon the resolution.

The Report was discussed by Messrs. J. J. Reynolds, Thos. Appleton and A. C. Harding.

The resolution was then presented to the Society, when it was moved and seconded that the resolution be adopted as read, the chair to appoint the committee. Carried.

Committee since appointed: Gen. Chas. FitzSimons, A. W. Wright and John Lundie.

Mr. A. C. Harding moved that the committee appointed on the financial condition of the Society be requested to report at the next meeting of the Society. Seconded and Carried.

The Secretary reported for the Board of Directors the following applications for membership:

Messrs. George David Stonestreet, Melville S. Hawkins, Charles C. Stowell.

A telegram was read from Copake Iron Works, New York, announcing the death of Mr. I. C. Chesbrough, a life-member of the Society.

Mr. J. J. Reynolds moved that a committee of three be appointed to draw up suitable resolutions on the death of Mr. Chesbrough. Seconded and carried.

The President appointed Messrs. Reynolds, Randolph and Benezette Williams. Upon Mr. Reynolds requesting to be relieved, Mr. Cooley was appointed in his place and Mr. Randolph named as chairman.

There being no further business the paper of the evening on "Comparative Tests of Two Smoke Consuming Devices for Steam Boiler Furnaces," was read by Mr. J. C. McMynn.

The discussion was participated in by Messrs. Gillespie, Harding, Barker and the President.

Mr. L. E. Cooley upon being called upon by the President delivered his promised contribution to the question of "Deep Water to the Atlantic."

Adjourned. John W. Weston, Secretary.

THE CIVIL ENGINEERS' CLUB OF CLEVELAND.

February 14th. 1893. The meeting was called to order by President Rice. The applications of N. B. Dare, John B. Davis, W. T. White, F. J. Falding for active membership and W. W. LaChance and J. W. Willard for associate membership, were read.

The committee on nomination of officers for the coming year reported as follows.

For President, A. H. Porter, C. M. Barber.
Vice-President, C. S. Howe, M. W. Kingsley.
Secretary, F. C. Osborn, E. P. Roberts.
Treasurer, C. P. Leland, E. H. Jones.
Librarian, C. H. Benjamin, C. L. Saunders.
1st. Director, C. W. Wason, John Walker.
2nd. Director, J. N. Richardson, Jas. Ritchie.

The tellers reported that Edward Charles Cooke, John Ross Bitner, Samuel Groves, Willett Warren Read, Charles Frederick Uebelacker and Charles W. Foote had been elected active members and Alvin Irwin Findley and James Wood associate members.

Mr. Follett of Chicago was present and spoke on the subject of accommodations for the club at Chicago.

On motion of Mr. Osborn this subject was referred to the Committee on Columbian Exposition.

The President appointed as the Committee on Annual Banquet the following: M. Baackes, chairman, Wm. T. Blunt, Geo. Bartol, Wm. L. Otis, E. P. Roberts, J. N. Richardson, James Ritchie. Col. J. A. Smith, Wm. H. Searles, John Walker.

Mr. Culley spoke of the work of the Ohio Society of Civil Engineers and stated that the next meeting of the Society would occur in Cleveland. The following resolution was adopted:—

Resolved:—That the Civil Engineer's Club of Cleveland express its pleasure at the action of the Ohio Society of Surveyors and Civil Engineers, in selecting this city for its 15th annual meeting in January 1894.

That this club extend a hearty greeting to said Ohio Society and a cordial invitation to the hospitalities of this club, during said annual meeting.

That the President of this club appoint a committee of three members of the club to act with the local committee of the Ohio Society in making arrangements for the entertainment of said Society.

That the Secretary of this Club, transmit a copy of this resolution to the Secretary of the Ohio Society of Surveyors and Civil Engineers.

Adjourned. CHAS. S. HOWE, Secretary.

MONTANA SOCIETY OF CIVIL ENGINEERS'.

NOVEMBER 12TH. 1892. Regular monthly meeting of the Society was held at the office of Messrs. Sizer & Keerl, Atlas Building, on November, 12th., 1892 at 8 o'clock p. m. President Haven in the chair. There were present Messrs. Keerl, Foss, McNeill, Haven and Jones. Minutes of the last meeting were read and approved. Mr. Keerl as the committee on papers to be read at the Engineering Congress to be held at Chicago during the World's Fair, reported progress.

The Committee on Topics reported that several papers had been promised, but that nothing had been received at that date.

A discussion followed and the views of those present were to the effect that either a paper or a topic for general discussion should be presented at each meeting.

Mr. Haven made a report as Chairman of the Committee on State Engineer which was to the effect that circular letters had been sent to all prospective members of the legislature, and that replies received were in a measure encouraging; he hoped to submit a final report to the Society at the annual meeting.

The Society then adjourned until the next regular meeting.

G. O. FOSS, Secretary.

SPECIAL MEETING, DECEMBER 30TH. 1892. A call for a special meeting having been signed by three members the President instructed the Secretary to give notice of the meeting through the newspapers. There were present Messrs. Keerl, Foss, Whitcomb, Herron, Haven and Jones.

The President stated the object of the meeting, which was to consider a bill which had been prepared for introduction into the coming session of the Montana Legislature entitled, "An Act to establish Irrigation Departments, and to Create a State Irrigation Commission, and to Define the Powers of Each." This bill had been prepared by parties outside of the Society and the Society had been requested to review its provisions and make suggestions upon any improvements appearing necessary.

Upon motion Mr. Foss read the bill complete, and it was afterwards taken up by sections and fully discussed. It was moved and carried that the bill be referred to a special committee of three to be appointed by the chair who should indicate the changes deemed expedient by the Society and transmit the same to Mr. Donald Bradford, the originator of the bill, also to report to the Society at the annual meeting.

The chair appointed as such Committee, Messrs. Foss, Cumming and Keerl.

The meeting then adjourned.

G. O. Foss, Secretary.

Annual Meeting, January 14th. 1893. The regular annual meeting of the Montana Society of Civil Engineers was held at the High School Building in the City of Helena. Saturday, January 14th., 1893, at 2 o'clock p. m.

Meeting was called to order with President Haven in the chair. The following members were present: Messrs. W. A. Haven, J. S. Keerl, A. M. Ryon, G. O. Foss, A. S. Hovey, G. E. Ingersoll, F. D. Jones, A. E. Cumming, Fred P. Gutelius, J. M. Page, H. P. Davis, E. R. McNeill, Charles Tappan, A. F. Whitcomb, H. V. Wheeler, A. G. Lombard, F. L. Sizer, George Scheetz, E. H. Beckler, John Herron, H. P. Rolfe, and George T. Wickes, also Superintendent Young and Professor Merritt of the Helena Public Schools.

Minutes of the last meeting were read and approved.

The annual report of the Secretary of the Society was received, and on motion of Mr. Cumming it was ordered that it take its regular course and be submitted to the Trustees.

The annual report of the Treasurer of the Society was submitted and on motion of Mr. Jones was ordered received and referred to the Trustees.

On motion of Mr. Keerl it was ordered that the Society subscribe for the Journal as heretofore for each member of the Society.

The Society then proceeded to the election of officers for the ensuing year. The chair appointed Messrs Whitcomb and Sizer as tellers.

Officers elected: President, W. A. Haven; 1st. Vice-President, J. S. Keerl; 2nd. Vice-President, A. M. Ryon; Secretary, G. O. Foss; Treasurer, A. S. Hovey; Trustee, Finlay McRae.

Mr. Keerl as Chairman of the Committee on Arrangements reported the programme to be carried out at this meeting.

The following amendment to the constitution of the Society was submitted by Mr. Keerl and after reading was passed until the next regular meeting of the Society, same having been duly approved by the members present:

Proposed Amendment to the Constitution of the Montana Society of Civil Engineers.

ARTICLE XI.

Sec. 6. Any member of any other Society in the Association of Engineering Societies, in good standing, may become a member of this Society, when duly elected as described in Article IV of the By-Laws, without paying the initiation fee, and with a release from the annual dues for such period, not over one year, as he may show by certificate he has paid in advance in the Society from which he comes.

On motion the Society thereupon adjourned to inspect the new High School Building. This building is of fire proof construction and is finished in a most thorough and workmanlike manner.

Upon re-assembling a paper was read by Mr. Neustadter entitled, "Method of Plumbing a Mine."

Mr. Foss exhibited to the Society a comparative profile of all the trans-continental railway lines except the Southern Pacific R. R. He pointed out the leading features of the different lines, stating the maximum rates of grade, total rise and fall, and length of each line.

Upon motion the Society thereupon adjourned until eight o'clock p. m

Evening Session. The meeting was called to order with President Haven in the chair. Upon motion the Secretary read a letter from Mr. F. D. Ross and also a communication from Mr. Corthell, both of which were ordered placed on file.

Prof. A. M. Ryon being called responded with a paper entitled "Engineering Education in Montana."

Mr. McNeill being called responded with a paper entitled "Lining of the Wickes or Boulder Tunnel."

On motion of Mr. Keerl a short recess was taken to enable the members to examine the plans exhibited with Mr. McNeill's paper.

Mr. F. P. Gutelius being called responded with a paper entitled "Construction of the Reservoir and Wooden Pipe-line of the Butte City Water Company."

The Secretary then read a bill which has been introduced into the Montana Legislature entitled "A BILL for an Act to Establish Departments and create a State Water Commission, and to define the powers of each."

The bill provides for a Board of four commissioners who are to control all the waters of the State for irrigation purposes, to condemn existing works and water rights, to establish the rate of water rents and levy taxes; also for an issue of bonds for the construction or purchase of irrigation works. All new works are to be constructed and all monies expended by the commission.

A somewhat lengthy discussion of the bill and of the irrigation question ensued in which Messrs. Keerl, Sizer, Herron, Davis, Rolfe, Ryon, Lombard, Page, Tappan and Foss took part. A letter on the subject was also read by the Secretary from Mr. C. L. Griffith who was unable to attend the meeting. The following resolution was unanimously adopted:

Resolved, that this Society favors the control by the State of all the waters available for irrigation purposes, and also the constrnction of irrigation works by the State, provided that suitable safe-guards are enacted for the protection of individual rights and the proper disbursement of moneys. We, do not, however, consider the provisions of the bill now before the Legislature adequate for the purpose for which it was designed. We would also recommend that the engineering work should be under the direction of a State Engineer appointed by the Governor.

On motion of Mr. Keerl the Society extended its thanks to members who submitted papers, and the Secretary was instructed to thank in writing the Board of School Trustees for their kindness in giving free of charge the use of the High School Building to the Society for its annual meeting.

On motion of Mr. Keerl a committee of three, consisting of Messrs. Wheeler, Page and Jones, was appointed by the chair to prepare a suitable bill to be submitted to the Legislature fixing the compensation of County Surveyors at $10. per day and expenses, instead of $7. as at present.

No further business offering, the Society thereupon adjourned.

G. O. Foss, Secretary.

WISCONSIN POLYTECHNIC SOCIETY.

25TH. MEETING, FEBRUARY 13TH. 1893. Present: 14 members, one guest. President Benzenberg in the chair.

The minutes of the previous meetings were read and approved.

The Annual reports of the President, Secretary and Treasurer were

presented and accepted, whereupon the election of officers for 1893 was taken up, Messrs. Scholtke and Poetzsch being appointed as tellers. The result of the election is as follows:

President, J. N. Barr.
1 Vice-President, W. F. Goodhue.
2 " " Chas. W. Boley.
Secretary, W. S. Mason.
Treasurer, M. A. Beck.
Trustee for 1893-96, Rich. Birkholz.

Upon motion of Mr. Geo. Mason a vote of thanks was extended to the outgoing officers for their services during the past year.

The President calls the attention of the meeting to the fact that the rental of the club room, which amounts to nearly $20 per month, is very high and that quarters could be had at a more reasonable figure elsewhere. Upon motion the Executive Committee is requested to inquire into the matter and report at the next meeting. The President further explains that a very desirable club room has been offered at No. 1 Grand Ave., where refreshments could be had if desired. It is proposed to try this new place by adjourning for it at once.

The rest of the business of the evening consisted in Mr. Koch's paper on, "The Engineer in the War—Cavalry Service," was transacted at the club room mentioned.

Mr. Koch's paper was received with a great deal of interest. It was followed by a sociable chat, the charms of which were greatly enhanced by seasonable refreshments and a frugal lunch.

Adjourned, 11:45 p. m. M. G. Schinke, Secretary.

CIVIL ENGINEERS' SOCIETY OF ST. PAUL.

February 6th. 1893. Regular monthly meeting of the Civil Engineer's Society of St. Paul was held at the Society Library at 8 p. m. 16 members, including the President and 6 visitors in attendance. Minutes of the previous meeting were read and approved. Messrs. Loweth, Morris and Stevens were named as a committee to consider the question of interchange of members. It was unanimously resolved that the U. S. Senators and Representatives in Congress for the State of Minnesota, also the Chairman of Committees to which has been referred the bill appropriating $40,000 for the continuance of the U. S. timber tests by the Forestry Division of the Agricultural Department be advised, by the President and Secretary of this Society, of the far-reaching benefits to the public and to the Engineering Profession which, in the judgment of this Society, the passage of this bill would procure.

Mr. F. S. Darling was elected to membership.

A paper on "Railroad Building in Mexico," was read by Mr. W. H. Wood. At present nine-tenths of Mexican imports enter via Vera Cruz. This port has no docks. All traffic must be pieced out by lighters. The recent harbor improvements at Tampico and the proposed direct line of railway to that port from the city of Mexico will probably divert much traffic to the new route. Deep water, docks, climate, railway grades and facilities will all be in favor of Tampico.

Mr. Chas. Steiner read the paper on the utilization of the Minnehaha water power previously presented before the Minneapolis Engineers Club.

C. L. Annan, Secretary.

ENGINEERS' CLUB OF MINNEAPOLIS.

February 9th. 1893. In the absence of both President and Vice-President, Walter S. Pardee was elected President Pro Tem.

Minutes of meeting of January 12th. were read and approved.

Prof. W. R. Hoag of the "Committee on Exchange of Membership Rights," reported progress and asked further time. Granted.

Prof. W. A. Pike in moving the approval of the minutes of the last meeting called attention to the fact that the "Tribune" had published a statement that the Club had approved Chas. Steiner, C. E., project as given in his paper; and moved: That the Secretary, be instructed to correct the impression that the club sanctioned his scheme to improve the Water power of Minnehaha Falls. Carried.

The recommendation contained in the Secretary's report, as to assessment, was then taken up.

A. B. Coe, Librarian, called the attention of the club to the fact of the necessity of binding its periodicals and hoped provision would be made for this.

Prof. Pike, moved: An assessment of $4.00 per member be made. Carried unanimously. He also moved: The Librarian be authorized to have bound the "Journals of the Association of Engineering Societies" and if possible he complete the set by exchange with members. Carried.

The proposition of the name of Prof. G. D. Shepardson for membership by Frank J. Llewellyn and W. R. Hoag was read.

Fred'k T. Llewellyn was present and completed his membership, promising a paper for the next meeting.

The severe snow storm raging had caused so small an attendance that no paper was read but after an informal social time, meeting adjourned.

Elbert Nexsen, Secretary.

ENGINEERS' CLUB OF MINNEAPOLIS.—CIVIL ENGINEERS' SOCIETY OF ST. PAUL.

Report of Joint Trip:—To West Superior, Wisconsin, Duluth and the Iron Range Mines by the Engineer's Club of Minneapolis, and the Society of Civil Engineers of St. Paul, Minn., as guests of the Civil Engineers at the head of Lake Superior.

In the latter part of October the Civil Engineers of West Superior represented by Eben F. Wells of the West Superior Steel & Iron Co., and A. S. Cooper, City Engineer, extended an invitation to the Engineeers' Club of Minneapolis, and the Society of Civil Engineers of St. Paul to visit West Superior and the Iron Ranges for a short trip some time in November; and finally on the 11th. of said month, the following gentlemen from Minneapolis and St. Paul, made the trip, viz:

Minneapolis: Wm. A. Pike, Fred Llewellyn, E. H. Loe, Elbert Nexsen, Carl Ilstrup, Christ Ilstrup, C. Oustad, A. B. Coe, Geo. W. Sublette, B. H. Durham, E. R. Dutton, G. C. Andrews, W. W. Redfield, W. R. Hoag, W. D. Van Duzee, C. Mathisen, F. W. Cappelen. —St. Paul: L. W. Rundlett, E. E. Woodman, A. O. Powell, C. F. Loweth, C. A. Annan, H. N. Elmer, Geo. W. Wilson, W. C. Merryman, Mr. Wilgus.

They were met early in the morning by Eben F. Wells, A. C. Cooper,

Henry Swenson, L. Klovdale, P. H. Smith, D. S. Smith, H. Thomas, F. B. Edwards, C. H. Webster, of West Superior, and D. A. Reed, L. Ayers, W. M. Lewis, E. W. Lewis, L. F. Brewster, L. S. Rice, of Duluth.

The entire party proceeded, by special train, to the works of the West Superior Steel & Iron Co., inspecting the Rolling Mills, the shops for structural work, and the Pipe Foundry.

The mills were busy turning out plates and angles for the Whalebacks, the new type of vessel now being constructed under the supervision of the inventor, Mr. Alexander MacDougall. The shops were partly finished, being enlarged to receive new machinery; amongst others some fine machines for the manufacture of the new Heath Rail Joint (invented in Minneapolis) on a large scale. These machines were not quite finished and their operations could not be observed. In the Pipe Foundry some 5 and 6 ft. pipes were being turned out for some of the North-western Railways to be used for culverts. The bids for next year's water-mains in Minneapolis, show that the West Superior people were under-bid by only one cent per ton by the firm that got the contract.

From this plant the party was taken to the new dry dock, the largest sweet water dock in the world, and thence to the Whaleback yards where it was met by the genial Captain Alexander McDougall, the inventor of the Whaleback and the daring revolutionist of the present navigating crafts.

Two Whalebacks were under construction, one being the largest of the kind ever built, the Columbus, 362 feet long, draft 12 to 18 feet, capacity five thousand passengers, and four thousand tons of freight. This vessel will be finished, ready for the World's Fair, and will handle a great amount of passenger traffic on the lake during the Fair. There were five hundred men working on the hull. The heaviest plates were of ½ inch metal and most of the material was ⅜in thick. The total amount of metal required was said to be 2500 tons, all manufactured in West Superior.

Captain MacDougall informed us that the Columbus would be launched the 3rd. of December. The following newspaper notices are of interest in the matter:

"West Superior, Wis. Dec. 5th. 1892. The first whale-back passenger excursion steamer was successfully launched Saturday before a crowd of 10,000 people, among them visitors from all parts of the country. The Christopher Columbus is the largest boat afloat on the lakes. Three months ago the material which now makes up the new steamer was pig iron. It was converted into angles and plates and on Sept. 6th., the first consignment was received at the yards from the Superior Steel & Iron Co. In just seventy working days, these plates and angles, and more which followed them, have been fashioned into the craft, which now lies in the launching slip situated at the Whaleback yards. The vessel has lines as fine as a yacht. The Christopher Columbus was built for the World's Fair Transportation Co., and for the especial purpose of carrying passengers. She can accommodate 5,000 passengers."

"At West Superior last Saturday afternoon, was launched the steel Whale-back passenger steamer, Christopher Columbus—the latest realization of maritime architecture. From the tiny wooden barks, the Pinta and Santa Maria, in which Columbus made his voyage of discovery, to the great steel five-decked and seven-turreted Whale-back, which bears his name, is a leap of invention and industrial progress, which well typifies the strides of development which have taken place in the intervening four centuries.

With her heavy steel frame 362 feet long, her 4000 tons displacement, 2,600 horse power, and capacity for five thousand passengers, the new Whale-back could easily transport on its decks and in its hold several entire fleets and crews like that of the great discoverer. And this mighty triumph of maritime architecture was constructed several thousands of miles inland from the coast which he discovered, constructed in the very heart of the then unexplored continent, cf iron dug from hills nearly as far inland, as the spot where Columbus landed was distant from the land from which he sailed.

During the four hundred years intervening between the discovery and its anniversary, it transpires that the seat of marine architecture is moved Westward nearly one-third the circumference of the earth, and the crown of superiority is given to a people who dwell on an inland fresh water sea, in what was then the unknown center of an unknown wilderness, and what is now the wheat granary and the first iron and lumber region of the earth, and the head of civilization's greatest geographical and industrial basin."

The Whale-back has a rather flat bottom, no keel at all, the stem is rounded off gradually to a cylindrical form. The hull proper is rounded off towards the deck, and in the Columbus, seven turrents act as main supports for the upper decks clearing the hull proper by about twelve feet. The ship looks top heavy but the surface exposed to wind and waves is smaller than on any sister ship of the same capacity afloat. Captain MacDougall claims that the waves striking the boat will run over the hull and the water disperse between the openings between the turrets and she will never be exposed to the full force of the waves and of course roll less than any other of the same size.

Captain McaDougall invited the party to his office, where he, in his magnificent style, entertained them relating his different schemes, always having a ready answer for every question. He had a beautiful model of the Columbus fitted up with electrical machinery and had previously let it run on the bay to his entire satisfaction. He was engaged upon a new war vessel that he expects will revolutionize the present system of naval warfare.

After leaving the bay works, dinner was partaken of at the West Superior House, and the entire party left for Duluth by steamer across the bay so as to take the afternoon train on the Duluth and Iron Range Road for the Vermillion and Mesaba Mines. A special car was placed at our service by chief Robert Augst, a member of the Minneapolis Club, who accompanied us as far as Two Harbors, where he turned us over to the superintendent of the Duluth & Iron Range Road, Mr. Owens, a most charming gentleman, who did everything in his power to make the trip pleasant.

Two Harbors is located on the lake about twenty-seven miles from Duluth. It is the shipping point for all the Vermillion ore output, and has splendid facilities for handling the material Although invited to spend some time there, the time could not well be spared to do so. Two Harbors is at the foot of a very heavy grade running for some eleven miles to Station Highland. The maximum grade is 137 feet per mile going North, bringing one up 1,760 feet above the sea, to the divide, or 1,158 feet above Lake Superior, going South the maximum grade is 66 feet. The maximum curve is 7 degrees. The Mesaba Range is 1,610 feet above the sea. Vermillion Lake is 1,373 feet above the sea.

Mr. Owens entertained the party with matters pertaining to the construction and maintenance of the road, which is 115 miles long to Ely, the terminal point, Tower being 21 miles South of Ely. The rails are being gradually changed from 56 to 80 pounds and the road double tracked. Although on the excessive grade from Highland to Two Harbors the handling of a loaded ore train is difficult, only one accident has occurred. About a year ago the engineer lost control of a train. The train crew saw it, and uncoupled the caboose, thereby saving themselves. The train left the track and was smashed to splinters. The foreman and engineer were hurt but recovered.

During the trip towards Tower it was deemed advisable not to go on the Mesaba Range, where the work at present is only surface strippings, but to go right through to Ely where we would stop over night and visit the mines and return next morning to Tower. Arriving at Ely, the party was divided between the two leading hotels of the place, viz:—The Oliver, and The Exchange. After resting and eating supper we were met by Superintendent Pengilly of the Chandler mine, who took us to the power house. The machinery is all from the Allis Works. Four six foot drums are operated and 1⅛ in. steel cables are used for the hoisting. These last from 14 to 16 months.

The Chandler Iron Co., is mining on 80 acres of land, having four shafts. No. 1, 300 ft. deep; No. 2, 402 ft. deep; No. 3, 359 ft. deep and No. 4, 450 ft. deep, all vertical. Drillings have been made 160 feet below the lowest level and ore found. The machinery was started in 1888 and the progress is readily shown by the following statements that in

1888	the	output	was	57,000	tons.
1889	"	"	"	303,000	"
1890	"	"	"	336,000	"
1891	"	"	"	373,000	"
1892	"	"	"	650,000	"

The mines are worked in two shifts of ten hours each, and the wages range from $1.65 to $2.32 per day. The miners are of different nationalities, Scandinavian, Hungarian, Poles and Welsh, the latter making the best miners.

Heavy timber is used throughout. The headings are about 11 by 12, bents 4 feet apart. The roofs are supported on 4 slabs. After all ore has been removed, the "sand" is let down and used as back filling, causing large depressions and fissures to show upon the surface.

The entire party examined the mine, all going down by the cage, although according to the State law the ladder should have been used. The mine was lighted by candles only.

The town of Ely is a mining town, and care is taken that the money earned is spent at home, i. e. in Ely.

The next morning the special took us back to Tower where the time from 9 A. M. to 3 P. M.. was spent in examining the finest mines in the State if not in the country. The deepest shaft is 558 ft. on a slight incline. The formation is quite different from that of the Chandler mine; very much less timbering is required and much larger headings are worked. The method of payment of wages is also different; the men take a contract for so much a foot and can work as much as they please. The Tower mines have arc electric lights, besides the candles there being no danger of the miners seeing too much. The danger at the Tower mines is in the "hangings," that is, the nearly vertical soapstone walls following up the ore.

These "hangings" are therefore occasionally supported by ore pillars and arches left to support the walls.

The company has large machine and blacksmith shops and everything is in fine shape.

The country is very rough and broken, and everything is red, and in Tower and Ely the opportunity for utilizing and accumulating red paint was abundant. The air compressor plant is located at the shore of Vermillion Lake north of the mines. This lake is one of the most beautiful imaginable, some 40 miles in length, full of islands, and must be a magnificent sight in the summer time.

The drainage is towards Canada, Allis engines are in the lead as at Ely. The following statements might be of general interest:

Duluth's Ore Output.—"The shipments show a total of over 1,000,000 tons."

Duluth, Nov. 27th. 1892:—The Duluth ore shipping season is practically concluded for 1892, though one more cargo of 1,900 tons of Vermillion ore may go down.

The total shipments of Vermillion Range ore were 1,155,490 gross tons as compared with 885,520 a year ago, and 62,122 in 1884, when the first seasons shipments were made. A grand total of 5,175,683 gross tons have been shipped during the nine seasons since the range was first developed. Besides this the first two cargos of Soft Mountain iron from the New Mesaba Range aggregate 4,500 tons. Vermillion shipments next season, with the two new mines, the Pioneer and the Zenith, which are to be actively operated, are likely to reach 2,000,000 tons.

Another notable deal was practically made last week, whereby the Great Western Iron Co. sells forty acres of its property on the Mesaba to Detroit and Cleveland parties for $300,000.

Ore to the amount of 800,000 tons has been shown up on nine acres and drills are down only 24 feet.

Hard Minnesota Ores.—How to Restore Their Supremacy Taken by the Mesaba Softs. From the Vermillion *Iron Journal.*

"The hard ore mines of the Lake Superior districts, while not threatened, have been made to feel the possible injury to their markets in consequence of the development of soft iron ore mines on the Mesaba Range.

Furnace men have been showing a preference for soft ores owing to the greater convenience in handling and working that product at the furnaces. While as a rule the hard hematites are higher in metallic iron than the soft, the furnace men have been willing to overlook this important fact, in consideration of the advantage in working soft ores. Hence the Vermillion and Marquette ranges with their hard ores, are those more particularly called upon to face this matter and it has remained for a Vermillion Company to take the first step toward overcoming the difficulty.

The Minnesota Iron Co., has this week received a 23 ton ore crusher, the first ever built to crush ores in competition with soft hematites. Its jaws are large enough to enable it to take in a chunk of ore 20 x 24 in. and break it into pieces small enough to permit of its convenient and easy smelting.

The powerful machine is to be located near the mouth of No. 8 shaft, the hoisting apparatus of which will be altered so as to permit of the car being elevated fully 15 feet higher than at present, when the ore will be dumped on an immense sieve. The small chunks will drop through into

tram cars below, while the large ones will be conveyed to the crusher near by, after passing through which the ore will be also dumped into tram cars, and thence to the stock pile or ore cars.

The foundation for this crusher and the engine that is to run it are now being put in. If the undertaking is a success, crushers will be put in at all of the shafts at the Minnesota, and the system eventually adopted by the Marquette Companies, which are now watching the developments in this city with great interest.

If the crusher is found practical and the system is demonstrated to be a success, it will serve largely to place the hard ore mines again in supremacy, as its product is higher in iron, and carries less moisture, hence a more desirable ore.

Less timber is used in hard ore mines than in soft, and in such a mine as the Minnesota immense stopes are broken readily and cheaply. These advantages will doubtless offset the extra expense of crushing. Then with this accomplished, the hard ore companies will have the point of better quality to present in favor of their product."

After a vain attempt to get rid of the surplus red paint in Tower, and partaking of a dinner, the price of which had been elaborately raised for the occasion, we began our return trip to Duluth where we arrived at 8.00 P. M.

The Duluth Engineers invited the whole party to spend Sunday with them in Duluth where they proposed to entertain us as royally as the West Superior gentlemen had done. Time did not permit us to accept the kind invitation, but during the evening we were the guests of the Duluth Engineers, who banqueted us at the Spaulding Hotel and afterwards took us to "The Incline."

"The Incline" is a double track elevated road running two cars, one going up and one coming down, with a seating capacity of 300 each when hard crowded. It runs from West Superior St. to the top of the hill. On this upper plateau, an electric street railway provides for the necessary transportation to the surrounding residence property. A most magnificent view is obtained from a beautiful pavillion erected at the top of "The Incline."

After midnight the entire visiting party departed for St. Paul and Minneapolis via the Omaha & Duluth Roads, which most kindly furnished free transportation both ways.

It would be fair to say that everybody enjoyed the trip, and that new relations have sprung up between the engineers of the Twin cities, which in the future can have none but the best results.

F. W. CAPPELEN.

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NOTES ON ENGLISH RAILWAYS.

BY E. K. TURNER, MEMBER, BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read November 16, 1892.]

During the summers of 1891-2 the writer had an opportunity to look over some of the English Railways. The impressions received during these rather hurried trips are recorded in the following notes.

The location of many of the Railways seems to have been governed by considerations other than the simple desire to get the best possible line, regarding the natural surface and features of the country. In many places strict regard for engineering principles does not account for work, which can only be explained by the evident desire to avoid injuring certain property lying in the natural line. In many cases changes were made to escape the payment of excessive sums for property damage, in others to meet the wishes of some powerful proprietor, whose enmity would have been injurious, perhaps fatal to the enterprise.

Especially in the earlier days of Railway construction, powerful interests in Parliament were used to extort money from the Companies, in the form of payment for property damaged. Many times its value being in some cases paid for property owned by persons having influence which might defeat the proposed Railway. Public opinion has in a measure checked this abuse in later years, but even now there is a remnant of the same, to be met by those having charge of new enterprises.

It must be kept in mind that England was thickly populated at the time Railways were begun, and that outside the cities, the wealth and population have increased but slowly. These conditions are so unlike

those found in this country, where the Railroad often precedes the settlement and development of the country, that it is scarcely possible to make comparisons.

Each projected Railway or extension of existing Road must receive sanction of Parliament in a special Bill. The Parliamentary bill or charter contains not only the right to build under certain restrictions noted in the bill, but also conditions as to operation, and charges to be permitted for transportation of the different classes of passengers and freight. This has led to complications in the course of time. Conditions which were perfectly fair and right years ago, are now manifestly unjust or obsolete. Recently there has been an attempt to modify many of these charter rates and regulations, largely in the interest of the Traders, as the customers are termed, but it is difficult to arrive at a fair solution of this question by a Parliamentary Committee.

The bill or charter can only be obtained after Committee hearings, at which all who appear have a chance to be heard, and the opponents of a measure seldom fail to appear and urge all objections in full.

The requirements of Parliament regulating the introduction of new bills are very strict. Plans and profiles of the line showing every detail of location and construction, and estimates in detail of cost, must be presented with the Bill. These details are attacked by the opponents of the Bill and must be defended by its friends, often leading to a long and bitter fight over points which with us would hardly be considered by any tribunal, except perhaps in settlement of damages.

The cost of these Parliamentary hearings is very great. In a recent article in one of the English papers, it is estimated that the expenditure during the thirty-five years between 1855 and 1890 was about twenty-five million pounds, or one hundred and twenty-five million dollars. During that time eleven thousand, eight hundred miles of railway were constructed, giving a cost for Parliamentary work, of ten thousand six hundred dollars per mile of road built, equal to the total cost of many American roads.

The bills presented during the same period covered forty-three thousand miles of proposed Road, making twenty-nine hundred dollars per mile on all lines presented to Parliament.

This large expense which must be provided for by the projectors or promoters of the Road, prevents the presentation of any enterprise without proper financial backing. In this way it prevents many speculative schemes from being brought forward. The projectors are required to deposit a large sum to cover expenses, before the question can be presented to the committee.

In carrying out the provisions of special and general acts the work of construction and, afterward, of operation are largely under control

of the Board of Trade, which has powers and duties corresponding to those of our Railroad Commission, with, perhaps, rather more direct control over the railways.

The capitalization of the English railways is very heavy, there being something over eight hundred and fifty million pounds invested at present. The total mileage is something over twenty-one thousand miles, making the cost per mile forty-five thousand, five hundred pounds, or two hundred and twenty thousand dollars. The average cost of Massachusetts railroads is $76,700.00, of the United States $59,-800 per mile. The average dividends last year were nearly four per cent., some roads paying as high as seven per cent. This high capitalization is due partly to the items already noted and partly to the more permanent and costly construction, also to the fact that a larger amount of rolling stock is provided in proportion to the mileage than in this country.

The construction of English railways is done in a more thorough manner than with us. The cuts and fills are made wider and great attention is paid to thorough drainage. The slopes both of cuts and fills are trimmed and turfed and kept in good condition. This in the moist climate of England can be done without trouble.

The material used for ballast is gravel, broken stone, or slag and cinders from furnaces, in some cases burnt clay or bricks broken in small pieces. The burnt clay is prepared by mixing clay taken from the railway cuts with sand, and burning small lumps in heaps or kilns, using old ties for fuel; the lumps are broken into small pieces and used in the same manner as broken stone for ballast.

Regarding the form or cross section of cuts or fills there is as great variety as with us. Some cover the ties entirely with ballast, others leave the greater part of the timber exposed to the air.

The structures are, as a rule, heavier and of a more permanent character than with us. In many places masonry bridges have been built where we should use wood or iron; but in this particular the modern practice in both countries is drawing more closely towards the application of the same principles.

The extensive use of brick in construction is particularly noticeable, a large hard brick of dark color being used; these make good work for culverts, arches of moderate span and retaining walls, and look better than cheap stone work. Many of the brick used in this work are nearly double the size of those commonly used here. No attempt is made at selection of shades or colors; as a consequence the work looks rougher than it would if a little work at culling the brick were done.

On some of the older railways cast iron is still in use for short span bridges, and in combination with wrought iron in longer spans. These are the same structures which were put in when the Roads were

built. The cast iron is now being taken out as fast as possible. Several minor accidents having occurred which have given warning, the roads have for the last few months been making every possible effort to replace all doubtful structures.

The breaking of a cast-iron girder on one of the roads having led to an investigation of its structures, an examination was made by an engineer who is an expert in such matters ; his report recommends the immediate renewal of twenty bridges, and that as soon as practicable eighty bridges be replaced by better structures. At the end of his report he states that the railway under examination is not alone in its need of stronger bridges. From information received from those in charge of this department, and from personal observation, it would seem to the writer that the better class of roads in America are not behind the English railways in the matter of safe bridges. The form of bridge used is generally the riveted lattice or plate, very few pin connected bridges being seen. A visit to the Forth bridge was full of interest, a great deal of information being received from the engineer in charge. It has proved very expensive in comparison with the gains derived from it, and will be probably for many years a financial load for its owners.

The ties on nearly all of the railways are of pine and Norway fir, sawed to dimension, five by ten inches and nine feet long. The greater part are treated with some chemical preservative, and last from ten to fifteen years, according to the tonnage passing over them. The cost of handling and treating is moderate, being on the Great Northern Railway from twelve to fourteen cents per tie. Most of the ties are imported and are treated at the port of landing, thus saving the cost of at least one handling and avoiding the cost of transportation to the treating plant, as would be necessary on a road buying its ties along its own line.

Most of the railways use creosote oil in treating ties and timber. The London and Northwestern uses 3½ gals. per tie. The rule on the Great Northern is 35 gals. per fifty cubic feet; their contract price last year was 11s. 6d. per fifty cubic feet. There are not as many ties used as with us, being spaced three feet between centres instead of two feet or less, as is customary in this country.

Various kinds of iron and steel ties are in use to a limited extent, but their use has not as yet reached beyond the experimental stage; but little if any saving in expense has been shown over timber. One objection has been in the difficulty of fastening the rail to the tie, but this has been overcome in great measure by some of the recently invented devices.

The rails are nearly all double-head or bull head. The weight now laid is about one hundred pounds per yard, having been increased

much faster in proportion to the weight of rolling load than with us. The rails are placed in cast iron chains, a chair to each tie under each rail. The rail is fixed in the chair by a wooden block or wedge, and the chair to the tie by spikes and bolts, making an awkward arrangement for repairs. The large bearing surface of the chair on the tie prevents that cutting action, which is so destructive to ties with us. This accounts in part for the difference in life of ties.

In designing the double-head rail, it was at first intended that after one head had become worn the rail should be turned over and the other head used, but in practice it is found that the worn head cannot be held in the chair properly and that the lower head becomes worn at the points of contact in the chair, so that the proper line and surface cannot be obtained with turned rails, hence the rails are seldom used but once. The latest designed sections are made with unlike heads, the attempt at reversing having been abandoned, and more attention is paid to making a section which will be stiff and present a good wearing surface.

The gauge of nearly all the railways is the same as our standard, four feet eight and one-half inches. Up to June of this year there still remained on the Great Western some of the original seven-foot track, but during that month the last of the broad gauge was removed. The narrow gauge was never received with much favor in England, and there are but few short lines in existence.

Generally, plain splice bars are used at the joints. In some cases a special chair is placed at the joint, but it is becoming the common practice to make a suspended joint. The weight and shape of rail is such that there is not the same trouble experienced in keeping joints in good condition as with us. Splice plates twenty inches long, with four bolts, are used at present.

One peculiar point noted was, that on a large part of the tracks the joint bolts are placed with the nut towards the middle of the track instead of outside as we place them. The greater depth of rail permits this to be done without danger of cutting off the nuts by wheel flanges. The only reason given for placing the bolts in this way was that the inspector could more easily detect loose bolts and tighten them.

Frogs and switches are similar to those in use here. The switches even at small stations are operated from cabins, with interlocking devices for switches and signals. Very few switch stands and targets are seen. When not connected with cabin and distant signals the switches are thrown by a ground or jackknife lever, with heavy weights on lever instead of lock.

Block signals are in use on nearly all of the English railways, the length of block being proportioned according to the amount of traffic.

The interlocking apparatus is much more cumbersome than with us; there are fully one-third more levers in use for the same movements. One engineer in charge of signals in answer to a question as to why they did not simplify their apparatus, stated that their men were used to their system and they did not consider it safe to make changes. The signals are generally of the semaphore form, although on some roads disc signals of various forms are used.

Within a few weeks a description has been published of the changes in signals at the Waterloo Station in London, which shows some radical changes in methods, and that the operating parts are concentrated as fully as would be done here.

The expense incurred on account of signals seems very large. On the London and Northwestern railway there are over five hundred men employed in construction and maintenance of signals, besides the much greater number engaged in their operation. At all important signals during fog or snow, men are stationed to notify enginemen of position of signal and to stop trains in case signals are against them. These men are provided with lanterns and fog signals or torpedoes, and add largely to the cost of operation.

The London and Northwestern system has over fourteen hundred signal cabins, sixteen thousand signals and thirty thousand levers.

Nearly all crossings of streets and public ways in the cities and large towns are over or under the tracks, large expense having been incurred to reach this object. In the country outside the larger places, about three-fourths of the crossings are also over or under. The benefits from this practice are now being felt; the number of trains having being largely increased, and at the same time the speed made greater. Trains can now be run at speed for long distances without slacking for crossings. The few crossings that are at grade are well guarded, gates being kept closed at all times, except when the crossing is being used by teams or people, and are interlocked with distant signals on the railway. This arrangement is now required by the regulations of the Board of Trade at all public crossings.

The entrance to nearly all of the large places is by tunnel, or by elevated structure, thus avoiding all present crossings and need of future crossings. As the growth of the place makes new streets necessary they can be built under or over the railway without interfering with it.

Crossing at the same grade by railways are very rare, and in some cases at junctions one track of the branch line is joined directly with the main line, while the other is carried over or under and joins the main track on the other side thus avoiding cross-over tracks and switches.

Yards are laid out with more care than has usually been the case in

this country, or perhaps the business having outgrown the old yards which, as with us, were of many years' growth without plan or system, they have been cleaned out and new ones built with a view to present larger needs. The same development is now taking place in this country on the older roads.

No facing switches are used on the main lines unless absolutely necessary. Throw-off or derailing switches are placed wherever there is danger of cars from sidetracks interfering with the main line. Posts are placed at points of clearance of approaching tracks. In many yards there is a light iron frame over one track, giving limit of size of loads permitted on platform cars, or wagons, as they are called.

The yard, and in fact nearly the whole line, is enclosed with neat and substantial fences or hedges, kept in good order. It would seem that the laws against walking on the tracks or trespassing on railway land are strictly enforced ; comparatively few people are seen walking on the right of way, other than the men at work there.

The repair of tracks on many of the railways in the vicinity of large cities, on account of the great number of trains, is becoming quite a difficult matter, and on many when the track needs anything more than minor repairs, a new track is put down, the old material being taken for use on those sections having lighter traffic. In this way the main track is kept in excellent condition even under the very heavy business in the vicinity of London.

The track repair force is organized about the same as with us. The track men carry their tools and small supplies in canvas bags on their backs, there being but little chance to use hand or push cars safely. The climate being milder than ours makes it possible to keep the track in good condition with less work and expense ; the ground is seldom frozen hard enough to affect it, and more work being put into the roadbed to make it permanent and drainage being more perfect, less labor is required in proportion to the business done to keep the track in good condition.

The track on the London and Northwestern Railway main line was in better condition than any other of equal length that the writer has ever seen. On most of the other large roads it is kept in very good condition, but not better than on many in this country.

As the accounts are kept in a different manner than with us, it is difficult to make a comparison as to the cost of maintenance.

The stations are generally more expensive structures than we have been accustomed to see in this country until recently. A very large expenditure has been made in the large cities on stations, and especially to get the stations as near the business centres as possible. This object has been attained by most of the railways entering London.

Many of them have spent one million pounds per mile to reach the centre of the city. The great terminal stations are monuments to their enterprise. This expenditure has proved a wise one in most cases, the increased business providing an increased amount of earnings large enough to yield a fair return for the capital invested.

In the London terminals some very good examples of train houses are to be seen. That of the Midland—St. Pancras Station—is two hundred and forty feet clear span, and seven hundred feet long, giving ample room for trains, and so arranged that carriages can be driven into it opposite the arrival tracks, so that a few steps take the traveller from his compartment in the train to his cab.

In London the underground circuit railways unite the principal surface railways and enable them to send their cars into and through the city, so that it is not necessary to change cars for those persons who wish to reach some other part of the city or other railway not connecting directly with the one on which they take passage. This is a great convenience after a person learns the system of connection and interchange between the railways. It also relieves the streets and surface transportation from much crowding.

The waiting-rooms in most of the stations are neat and comfortable, but little in the way of ornament is attempted. Three classes of passengers are provided for.

The platforms are placed about three and one-half feet above the rail, since all passenger cars are entered by side doors, with one step on the side of the car, eight inches lower than the car floor. Platforms have in most cases stone or concrete floors, and are in most cases wider than in this country. This provides for the quick exit of crowds, which leave the cars much more quickly than with us.

The country stations have considerable attention paid to architectural effect. Their surroundings are kept neat and in good order. They are all surrounded with substantial fences. Entrance and exit must be made through doors or gates provided for this purpose. No one is permitted to cross the tracks, bridges or sub-ways being provided. At all stations large signs are placed bearing the name of the station ; this is also placed on the lamps. The signs are in many cases rendered useless by the numerous advertising placards which render it difficult to pick out the station sign.

The freight stations in the cities are large, and those built within the last few years are well supplied with labor saving appliances, such as hydraulic cranes and capstans. Some very good examples of these appliances can be seen in the L. and N. W. stations at Liverpool.

At many of the terminal stations in London, owing to the value of land and the difficulty of obtaining it at any price, great ingenuity has

been shown in making the best use of limited quarters. In some cases cars are raised or lowered by hydraulic lifts, making two or three floors available for loading or unloading freight. The speed with which freight is handled in some of these freight houses is remarkable and shows what can be done in very limited space when there is perfect system. At some of the London stations especially, this is true, the greater part of the work being done in the evening and early morning, when the passenger trains are not so much in the way as during the day.

At the country stations but little is done in the way of furnishing buildings for receiving or storing freight, nearly everything being loaded directly on to cars or taken from them without going into a freight house. This is due partly to the fact that the carloads are small and therefore handled much more quickly than with us, also to the custom of providing canvas covers or tarpaulins for each platform car with which to cover the load or part of load on the car.

The locomotives on English railways at first give the America visitor the idea that something is lacking or unfinished; there are no pilot or cowcatcher, no headlight, no bell, and often no cab. But these locomotives do good service, and there seems to be present all of the parts necessary for business. No pilot is needed because there are very few crossings at grade and the tracks are kept clear of trespassers; for the same reason no headlight is needed. No bell is used because it is the custom to sound a whistle where we use a bell. The question of cabs is somewhat different; formerly none were used; later, boards with plates of glass set in them, were used by some who did not have the fear of violating established usage too strong upon them. These boards have grown so that now on some railways quite a respectable shelter is provided for the men, and the growth continues. But there are still to be seen many engines without the vestige of a cab. The finish of locomotives is very plain; there is little brass or bright color; on every part that can be painted there is a coat of black or dark green paint; this gives a solid and business-like appearance to the locomotive and saves expense in taking care of them.

So far as observed by the writer the number of locomotives in proportion to the work is larger than with us; the latest figures which are available giving annual mileage confirm this view, and show an excess of at least 20 per cent. The average train load is much less than with us.

Quite a number of compound locomotives were seen and the men using them report favorably on their performance. Some of the compounds on the L. and N. W. Railway have been in service over ten years. These are from designs by Mr. Webb, mechanical superin-

tendent. They have three cylinders, two outside connected with the rear pair of driving wheels, in the same manner as our outside connected engines; these two cylinders use high pressure steam; the low pressure cylinder is in the middle, connected with a crank axle on which are the forward driving wheels. The engines have an arrangement of valves by which high pressure steam can be admitted to the three cylinders at starting and afterwards cut off from the low pressure cylinder.

One of the most noticeable points of difference is in the driving wheels, some being of greater diameter than is used in this country, especially on those locomotives with a single pair of driving wheels, of which there are a large number in use; some of the express engines with a single pair of drivers, have wheels eight feet in diameter. The spacing of driving wheels to admit of better form of firebox is also noticeable. Still another point noted is the extensive use of the screw reversing gear instead of the lever.

Passenger cars, or carriages as they are called, are entirely different from ours, being built with compartments entered from the side, with no means of communication or passage between the compartments.

There are on most railways three classes, and frequently compartments for two or three classes in one car, each car having from four to six compartments. Some of the companies have given up the use of the second class, keeping, as they express it, the first and third. This was done largely with a view of reducing operating expenses, and seems to have accomplished its object. Previous to 1880 most railways limited travel on fast trains to first and second class, but now nearly all trains take all classes.

The proportion of carriages or rather of seats furnished by the L. & N. W. for different classes is fourteen per cent. first class, fourteen per cent. second class and seventy-two per cent. third class. But the proportionate number of passengers of the cheaper to the dearer class is even more than is shown by these figures. The total number of carriages in use by the same railway in 1888 was 4,500, which number has been considerably increased since.

First-class compartments are very comfortable, having seats for six persons, three facing the engine and three riding backwards. This gives ample room, as the width is seven and one-half feet and the length six feet. These compartments are upholstered in cloth, with good carpets; they are well lighted with a window in each door and one each side of the door. The window in the door lets down with a strap in the same manner as windows in coaches or carriages; each window has a curtain. In the centre of the roof is a large lamp, which is put in place from the outside by men walking on the roof. Over

each seat is a good-sized rack or netting for baggage, or as it is there called luggage, of which a large amount can be taken in the car. In one case the writer noted among other luggage a tin bath tub. As a general thing there is more hand baggage and less large trunks than in this country.

The second-class compartments are comfortable, not so richly upholstered as the first-class, but good enough. There is not so much room allowed to each passenger. The seats are narrower and closer, four or five people occupy the same width that is provided for three in the first class.

The third class compartments often contain little more than wooden benches, with a leather cushion, but on long distance travel are cheaply upholstered. These compartments are expected to carry ten or twelve people. They are often so much crowded that the knees of an averaged sized person seem very much in the way.

The older carriages, and, in fact, all but those built within the last five years, are short—twenty-four to thirty-two feet long—with four or six wheels fastened to the sills, with one spring between the sill and the oil-box on the end of the axle. With anything but the best possible track these carriages are not easy to ride in, every imperfection in the track being felt at once.

The later carriages are forty-two feet long, with four wheel trucks or bogies as they are called, similar to those in use here.

Nearly all of the passenger rolling stock is provided with train power brakes, some vacuum, others of the Westinghouse pattern. But few of the passenger carriages have hand-brakes ; before the train brakes were adopted, trains were controlled by brake vans or guard vans, which were placed at intervals of three or four carriages in long trains, and at each end of short trains ; these vans are still used in the trains ; the heavier luggage is placed in them, and sometimes light freight such as with us would be handled by the express companies.

Each train has a chief guard and more or less under guards, according to the length of the train. The chief guard corresponds to our conductor, except that in moving or starting the train at stations he is under the authority of the depotmaster. The under guards have to attend to about the same duties as brakemen with us, except that they do not *attempt* to announce stations.

Until recently there has been no means of communicating between the passengers and guard or engineman. There is now on most railways a bellcord somewhere within reach, and generally in the carriage a notice regulating its use and reciting the penalties attending improper use. In some cars having the automatic break, this can be set by the passenger by means of a bell-pull or crank connecting with the

air valves. In a few carriages of the latest make is found a closet or lavatory, as it is called, but in by far the greater number there is no convenience of this kind.

The only attempt at warming carriages in winter is by means of hot water cans, which are changed occasionally, and serve to show how cold it is. Some of the cans contain various chemical solutions designed to retain the heat longer than water. Experiments are being made in steam heating, but from the magnitude of the task of equipping such an immense amount of rolling stock, it will be slow of adoption for any but long distance trains.

A few sleeping cars and parlor cars of American style have been put on some of the longer runs, but have not proved very successful. During this year the S. E. railway has put trains of Pullman cars on its continental line—London to Dover—but as yet no report as to the success of the experiment has been published.

Some of the compartments of the night trains are provided with pillows and blankets and may be used as sleeping cars.

Carriages are coupled together with links and hook, having a screw attachment to bring them together and avoid slack; a spring buffer at each corner serves to prevent shock and unpleasant motion.

Regarding the number of cars in proportion to the travel the results seem to be about the same as in this country, many trains being seen with a large proportion of empty seats, especially of first-class, while some trains in the suburban service are badly crowded. This seems to be the rule at busy times of day, and is evidently one of those problems which trouble railway managers in England as well as railroad managers in America.

Freight cars, or wagons as they are called, are nearly all short four-wheel platforms; there are a few short boxcars and some stock cars, with slat sides and closed roof and ends. Four or five tons is a full load.

Painted canvas covers or tarpaulins are furnished with which to cover perishable goods. Making and repairing these covers is quite an important element in the cost of operation. The covers are painted black, with large white or red letters indicating the railway owning them; the rules require prompt return to the owning road.

Quite a large number of private freight cars are used, especially in the transportation of coal and iron. But most of the large companies are discouraging this usage, preferring to own the cars, both on account of safety and economy. Safety, because they take better care of their own cars, and make repairs when needed, while private owners are accustomed to make only such repairs as are needed to prevent the rejection of their cars. Economy, because railway companies can use

their own cars wherever they are most needed, while private cars must be returned to their owners without regard to the general need, thus keeping in existence a large percentage of cars more than the actual needs of business call for, and locking up a large capital in rolling stock which with railroad ownership might be applied to other purposes. On the other hand, the mine owner has his own cars to use whenever he wants them, instead of being dependent on the railway company.

The coupling on freight cars is the same as on passenger carriages, and the trains are controlled by the locomotive and brake vans.

The organization of the operating department is very nearly the same as with us. The methods of working are, of course, somewhat different.

The passenger business is handled very promptly, especially at the great terminal stations. The form of car enables a crowd to leave the train much more promptly than with us. There is a door for each compartment opening directly on to a wide platform, at nearly the same height as the car floor. One-half minute is generally long enough to clear a long train.

The amount of business handled at some of the London terminal stations is immense. At the Liverpool street station of the G. E. R. there are, according to Bradshaw's Guide, 314 trains out daily, and at the adjoining Broad street station of the North London Railway 287 outward daily: to this is to be added numerous extra and special trains run during the busy season. These are not the largest stations in London, but probably accommodate more people than any of the others.

The short distance trains are not switched at terminal stations, simply unloaded, loaded again and sent out, in the same condition as to arrangement of cars as when they arrive. Absence of baggage and express cars renders this easy. The other cars are so nearly alike that it makes but little difference as to their order or arrangement in train. The through express trains are switched in order, as they contain cars which are left at junction points for other railways, or for branch lines, often being dropped off without stopping the train.

The speed of express trains is greater than with us, quite a number being timed over fifty miles per hour, but so far as the experience of the writer goes these trains are not held any more closely to schedule time than ours. With the exception of the L. & N. W. trains very few of the long run trains were on time. In a journey from London to Glasgow via the East Coast line, and from Glasgow to Liverpool via the Midland line, the trains were nowhere less than thirty minutes late, and on the last part of the journey were over one hour late.

Baggage is handled in a very different manner than with us. No

checks are used. As much as possible is taken into the compartment with the passenger; what he cannot take with him is put into the luggage van and claimed at the end of the journey by the passenger, who points out his own. This would seem to be a very loose way to do the business and to furnish an opportunity for theft, but the writer was assured that there is seldom trouble from this cause, probably because the laws are promptly enforced, in case a person is found taking what does not belong to him.

The charges for long distance travel are: One penny per mile for third class, one and one-half for second class and two for first class. The proportion of each class is about four per cent. first-class, eight per cent. second, and eighty-eight per cent. third class. The third class is by far the most profitable on account of the small proportion of dead load hauled for that class, as compared with first, or even second.

Passenger and freight rates are regulated by an association of the railways, similar to the Clearing House Associations, which have at times been formed in this country. These rates must, of course, be within the limits prescribed by the charter. Rates, once made and approved, are not varied unless by authority of the association. Competition may be met in any other way but not by cutting rates. The companies have worked in accordance with this agreement for several years past. Previous to the organization of the association the competition was such that a continuance of it would have brought bankruptcy to the corporations.

In every way but rate cutting the competition is now very close. Most of the large towns have two or more of the large roads entering them, and have every facility for transportation of both passengers and freight which can possibly be offered. This competition is often carried to an unreasonable extent, as in the case of the Scotch business in 1889, when not only was the speed increased to a dangerous degree which could not be maintained, but trains were put on far in excess of the requirements of the business and structures built at a cost which it would seem impossible ever to get a return for, the Forth bridge being a notable example.

Collection and delivery of freight is done by the railways, each having its teams for this purpose at all important places, having offices or sub-stations scattered through the business parts of the cities. By this means everything which with us would go into the hands of the express companies and truck men, is handled directly by the railway. There are some advantages in this system both to the company and its patrons, but all things considered the writer does not think it a feature to be adopted by our roads at present.

The despatch given to freight, especially that of a perishable nature,

is greater than with us, a large portion being handled as promptly as express goods are with us. This is accomplished by the means already noted. First, receipt and delivery by the company's teams ; second, quick work at stations ; third, small cars, enabling freight for each station to be kept separate; fourth, prompt movement of trains. This movement of freight trains is carried to an extent unknown in this country. There are cases, such as trains carrying fish to London, and, in the season, fruit trains, where the freight trains have rights over passenger trains, and make quicker time.

Surprise is often expressed by visitors from America that the old methods and appliances are kept in use ; that large passenger cars like ours are not used, instead of the compartment carriages ; that the four wheel, short freight wagon is not displaced by eight-wheel boxcars, as has been the case in this country ; that checks are not used ; that cars are not warmed more thoroughly in winter. But after looking over the system and trying it under various conditions, the writer has become convinced that the changes noted, if ever made, should be made slowly. The business is compact and crowded into a small territory. There is little long distance travel in the sense that we use the expression. The rolling stock has been built to fit the structures, and any change in it would require an extensive alteration in tracks, bridges, platforms and stations, both as to their height and width. The rolling stock being narrow and low compared with ours, the structures have been built so permanently and at such cost, that to change them would add too much to the capital account, already as large as it should be, unless a large additional business is created or attracted by the change.

As to the use of checks, so long as so large a proportion of luggage is carried in the compartment with its owner, there is no doubt that it is handled more promptly than under a checking system, and so little is lost that the question of safety hardly enters.

Concerning the question of heating, there can be no excuse for not adopting some steam heating device, except that the expense would be large to fit out so much rolling stock, and that it would be necessary to furnish heating apparatus at nearly every station, cars being dropped from trains and taken on when needed much more freely than with us.

So far as the writer observed there are many more men employed in every department, than with us, in proportion to the business done. The wages paid, except to the higher officials, are less than in this country, so that the cost of work done will not vary a great deal.

Many of the large railways have within a few years established hotels at their principal stations, which are managed directly by the company through a hotel department, or in some cases by contractors.

This is a great convenience. These hotels, so far as the writer observed, are equal to or better than the same class not under control of the railway.

There are also many steamboat lines owned and operated directly by the railways, as in the case of the lines to Ireland, owned by the L. & N. W., and to France by the L., C. & D., and others. There seems to be no particular gain in this, and it would probably be better to keep the different kinds of business separate. The same remark will apply to the hotel business, it does not naturally belong to the railways.

Some of the larger railways carry on the manufacture of almost all articles needed in operation and maintenance, some even have their own rolling mill and roll rails and other forms of iron and steel.

In looking over the English railways no difficulty was experienced in obtaining permission to examine the roads and everything pertaining to them. On the other hand, everyone connected with them, from the manager to the laborer, seemed glad to answer questions and give every possible facility for learning their methods and seeing their appliances.

FIRE RESISTING CONSTRUCTION.

By William W. Sabin, Architect, Member Civil Engineer's Club of Cleveland.

In view of the large number of destructive fires which occur in this city, it seems as though the subject of fire resisting construction might be a profitable one for study.

It is proposed in this paper to present to you the various forms of fire proof and fire resisting construction now in use, and to show in itemized tabular form the comparative cost of the different systems.

Structures are fire proof when the constructive parts are composed of materials which are absolutely non-inflammable.

They are simply fire resisting, when a part, or all the materials employed are inflammable in their nature, but are so disposed and protected that the damage or destruction by fire is greatly retarded, and the flames are prevented from spreading through the building.

In a building of the first class, the following conditions must be observed:

(*a*) All outside walls to be masonry, or iron protected by masonry.

(*b*) All columns to be iron or steel.

(*c*) All floors to be supported by iron or steel beams or girders.

(*d*) All partitions or furring to be of incombustible materials.

The destruction of iron columns by small fires, shows that no pains

should be spared to thoroughly protect them from the heat. Their very expansion before they have been materially weakened by heat may cause their destruction.

The result in this case, is to raise the floors and their loads, and as this strain is much greater than is required to merely support them, our column may give way at the start.

Then again, cold water may strike the heated column causing it to bend by the sudden contraction of one side, and it may fail under a very light load.

The usual method of protecting iron columns is to incase them with terra-cotta blocks fastened together in such a way that each fastening is covered by the next block. All joints being filled with mortar.

Danger lies in the faulty application of some of the blocks. Some pieces may come loose and drop off in a fire, or break in pieces under the application of cold water, or be knocked off by some falling body.

Any of these accidents will expose the iron to the action of the heat, with a tendency toward the same results as if the column were entirely exposed, and with the system of bolting and riveting all parts together, the failure of one column means the pulling down of the adjoining sections and in that way the destruction of a great part of the building.

Then there is rust. While in cast iron this is not formidable, the rust only penetrating slightly and then apparently stopping, in wrot iron or steel, such as is used in modern buildings, the rust once starting never stops until the metal is entirely gone.

All the work is of course carefully painted before it is covered up, but it is impossible to prevent some parts being left exposed especially at the joints, and even if it were possible the paint protects the iron only so long as the oil in it lasts, and then any dampness develops the everlasting rust.

Iron beams and girders are subject to the same dangers that beset columns, with the additional fact that it is more difficult to perfectly secure the fire-proofing materials to the girders than to the columns, and this makes the danger of accidents to them even greater.

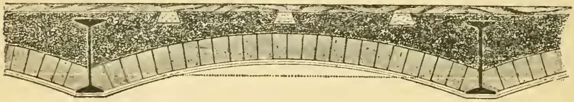
But we will pass from the columns, girders and beams, which, with some modifications are the same in all fire proof construction, to the floors, partitions and furring.

"**A.**" Of these the floors present the greatest variety. The oldest method is to place the floor beams about 5′ apart and turning a 4″ brick arch between them, tieing the beams together with iron bolts to resist the thrust of the arches. The space above the arches and between the beams is then leveled up with concrete in which are bedded strips of wood to which are nailed the flooring. The plastering is ap-

plied directly to the bottom of the arches and over the bottom flanges of the beams.

It was soon found that on the application of heat, the plastering dropped from the bottom of the beam and left it exposed, so a brick or tile skewback is now used which covers the bottom flange completely.

The weight of this floor excluding the floor beams is 70 lbs. to the square foot.



"A." Old style Brick Arch. Weight 70 lbs. per square foot.

"A." Skewback Tile for Brick Arches.

Aside from the matter of weight, this construction has never been surpassed. The Post-office is an example of this system.

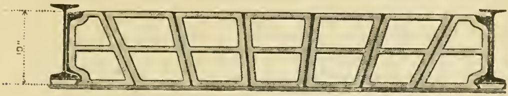
"B." A variety of this construction was to use a corrugated sheet iron arch in place of the brick, but as this left the flange of the beam as well as the arch itself exposed to the heat, the construction has no especial merit. The weight of this floor is the same as the

"B." Corrugated Iron and Concrete Arch. Weight 70 lbs. per sq. foot.

brick arch, 70 lbs. to the square foot. An example of this style can be seen in the building, No. 113, 115, 117 St. Clair Street.

In addition to their great weight, these two forms were objectionable also from the fact that the ceilings were a series of segmental arches, and so we take a long step ahead and come to the method most in use at the present day: the flat arch of hollow terra-cotta, made from fire clay.

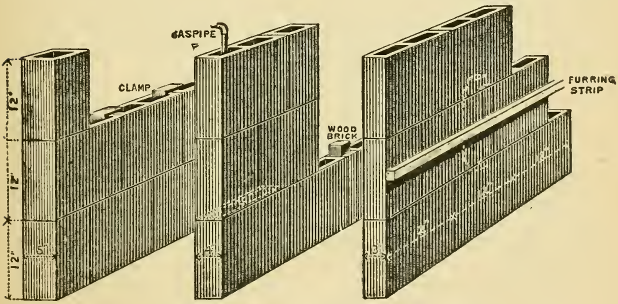
"C." This system was introduced in 1871. The average weight of this floor is 40 lbs. to the square foot, and the space between the beams is increased to 6′ and 7′.



"C." 10 inch Web Tile Floor Arch. Weight 40 lbs. per square foot.

We still have the tie rod to take up the thrust concealed and protected in the joints of the tiling. The lower flanges of the beams are protected by the skewbacks and the plastering is done directly on the lower surface of the arch.

A thin layer of concrete is put over the tops of the arches, and strips imbedded in that for nailing the floor to. The corresponding partitions and furring to go with this construction, are hollow tile from 2″ to 6″ thick. The blocks are clamped together and laid with

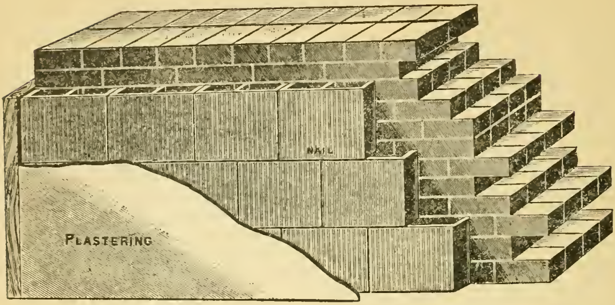


"C¹." Views of 3, 4 and 5 inch Tile Partitions.

mortar joints. All surfaces of these tile are ribbed to give a good hold to the mortar. This construction can now be viewed to advantage in the new Cuyahoga Building. Various devices, all more or less expensive, are used for securing door frames, casings, mouldings and other ornamental woodwork to this construction.

But the inventor is always at work.

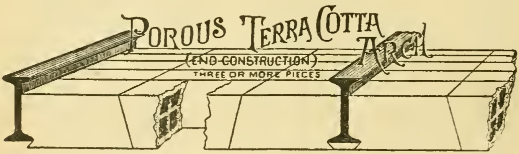
"D." He mixes saw-dust with his brick clay, and this being destroyed in the burning of the tile, leaves porous terra-cotta, a light firm substance which can be cut with a saw, and which will hold a



"C²." 2 inch Furring on Brick Wall.

nail as well as wood. It is made into the hard terra-cotta forms and at once largely adopted for partitions, and furring, but the arches do not stand the same loads.

Then the end construction is devised and the porous terra-cotta comes in competition with the older form. At Denver, trial arches of hard and porous terra-cotta were constructed of 5′ span and 4′ along



"D¹." 4 feet Span.

the beams. They were built in the most careful manner, and the experiments were conducted by the agents of the companies, and a well known firm of architects.

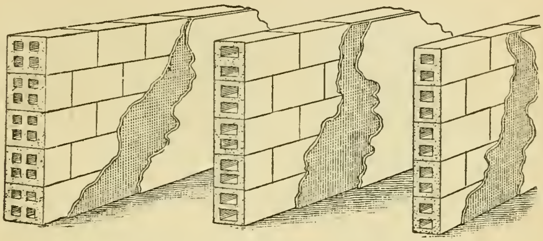
They were as follows:

The hard terra-cotta stood a dead load of 5,429 lbs., and broke suddenly, the skewbacks on one side failing. A measurement for deflection was taken under a load of 4,000 lbs. and found to be .012″.

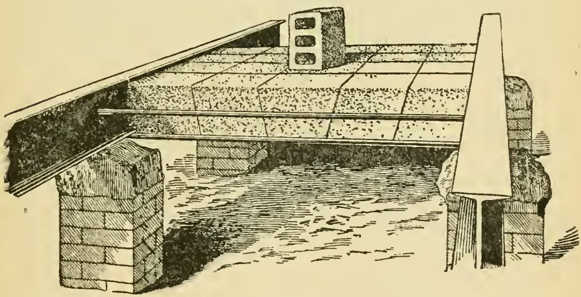
The porous terra-cotta arch withstood a load of 15,145 lbs. with a deflection of .065″, and when the load was removed, regained its former position, but subsequent tests by dropping showed the arch to have been much weakened.

For the drop test, the hard terra-cotta broke under the first blow of a 12″ × 12″ × 4′ block weighing 134 lbs., and falling from a height of 6′.

The porous terra-cotta withstood the first drop without apparent injury. The second broke a tile, but it took 11 drops of from 6′ to 8′ before the arch was entirely destroyed.



"D[2]." Partition Blocks are made all sizes, from 3 × 6 × 12 up to 8 × 10 × 12 in.



"D[3]." End Construction, Terra cotta Lumber. (Porous Terra-cotta.) Arch built ready for Testing.

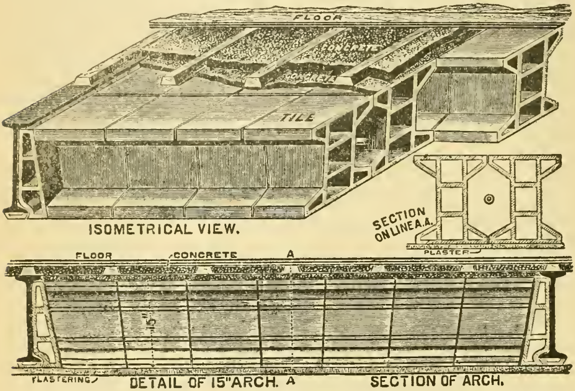
In the fire and water test, the hard terra-cotta arch was heated to a temperature of 1,350°, and on the third application of water was destroyed.

The porous terra-cotta arch withstood a temperature of 1,200°, and 11 applications of water and although rather disfigured, was still in place.

These tests go to show that the porous terra-cotta is a valuable material, and while the older form is amply strong to meet any require-

ments of practice, that the end construction is greatly superior in strength to the common method.

The result of this is that the end construction is now made in hard terra-cotta which the makers claim is the best thing yet. So much for tests. In actual practice the Chicago Athletic Club building and the Lumber Exchange Building of Milwaukee have been burned. Both in



"D⁴."

an incomplete condition. The former fire-proofed with porous and the latter with hard terra-cotta. In both cases the exposed woodwork was entirely destroyed, but the fire-proofing withstood the test of both fire and water, and the falling of heavy bodies such as safes without any great injury.

These are the only fire proof buildings to my knowledge in which a serious fire has occurred.

I think the limit of effectiveness has been reached in this direction, and now the constructors are turning their efforts toward arriving at similar results with less weight. As the case now stands, we have tons and tons of iron work and tons and tons of pottery, all to carry loads of a few hundred pounds.

The first step is to reduce the loads of the floors and thereby reduce the expense of the supporting iron work.

"**E.**" In the next method we will increase the distance between the beams to 12′ using a 12″ where before we used a 9″ beam, and suspend from them a galvanized wire mesh said to be able to withstand a load of 1,000 lbs. to the square foot. A frame is laid over the ironwork

"E[1]."

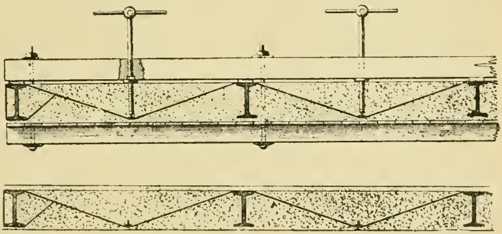
which supports the center boards below, and also screws which strain the wire mesh tight.

On top of the center boards the space between the beams is filled in to a depth of 8″ with a concrete composed of finely crushed coke, cork, cement and a little sand.

This is poured in and tamped until the wire mesh is thoroughly imbedded in it, and leveled up over the tops of the beams. The usual strips are laid in the concrete for nailing the flooring to.

The bottom flanges of the beams are covered with the concrete. The lower face of the concrete answers for the first coat of plaster.

The weight of this floor is only 18 lbs. to the square foot, so the saving in the supporting iron work is very great.



"E[2]."

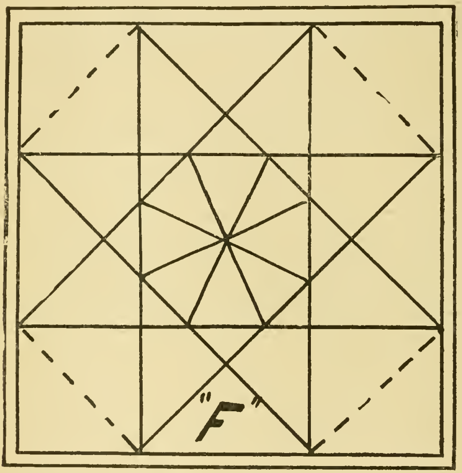
This floor has withstood a load of 580 lbs. to the square foot; with a deflection of $\frac{1}{2}''$ without apparent injury, and the systen is now being used in quite a number of large buildings.

"F." Another method which is now being put in a large office building in Brooklyn, is to divide the total floor space into panels about 25′ each way with lattice girders. These are spanned with a system of light metal arches, which are mainly of 3″ × 1″ bar iron, with a rise of $1\frac{1}{2}'$. The thrust of the arches is taken up by an octagonal frame of angle iron in each panel connecting their ends. All arches are bolted together at their intersections.

These arches are built into the lower part of concrete beams, which

carry the floors on the upper edges, and curved plaster soffits on the under side which form the ceilings. The concrete beams are pierced with port-holes for the circulation of air, and heat, and to lighten the construction.

The curved ceilings are moulded over a rubber bag filled with air, which is pressed up between the triangular panels formed by the intersecting arches. These rubber centers are held in place during this opera-

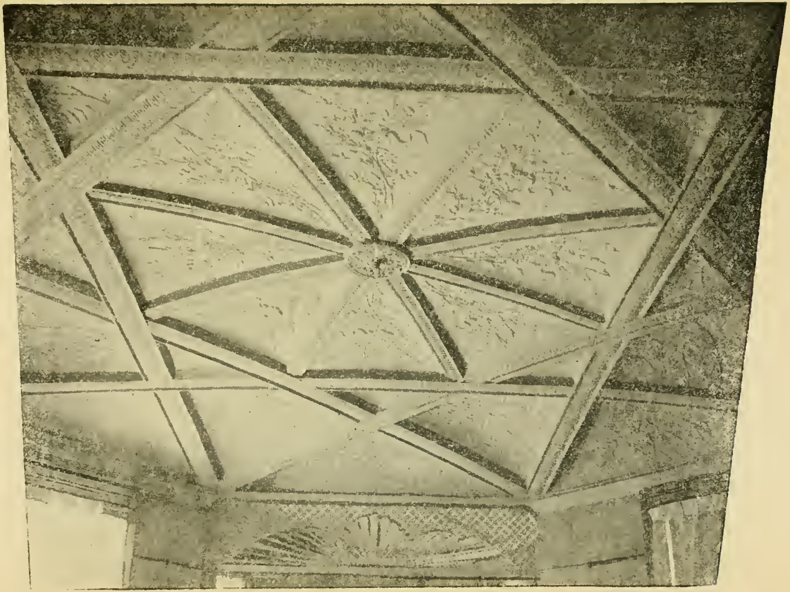


tion by an umbrella scaffold, and all the panels are formed simultaneously. The material for these soffits is plaster of paris and cement. The center of the floor is then filled in solid, on top of the $2 \times \frac{1}{2}''$ arches and the plaster soffits.

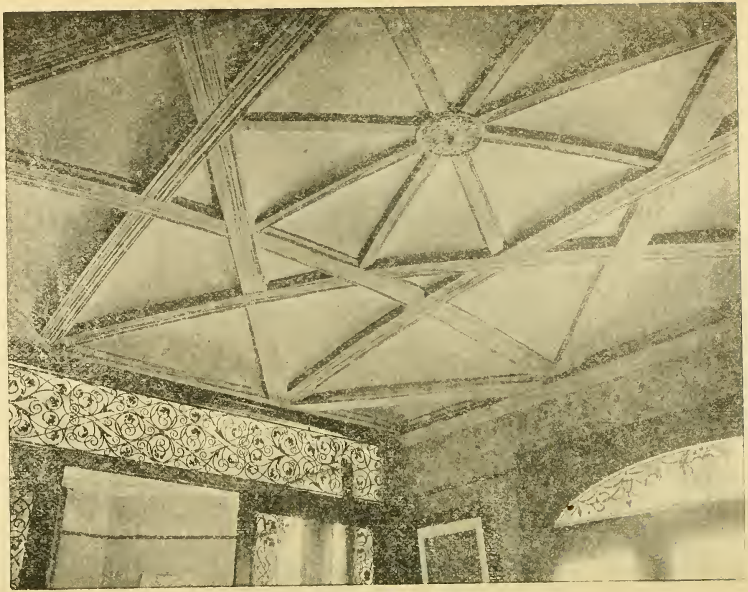
Over the balance of the figure, are stretched heavy steel wires, which in turn support galvanized wire cloth. Over this is put a layer of concrete 3″ thick in which are laid the strips for nailing the flooring to.

The inventor claims this floor to be equal in strength and fire resisting qualities to any of the older patterns. The saving in iron work by this construction is very great, inasmuch as the weight of iron is trifling in comparison with that in a beam and arch floor, and the shapes of iron used in this system do not cost anything like the price per pound for rolled beams.

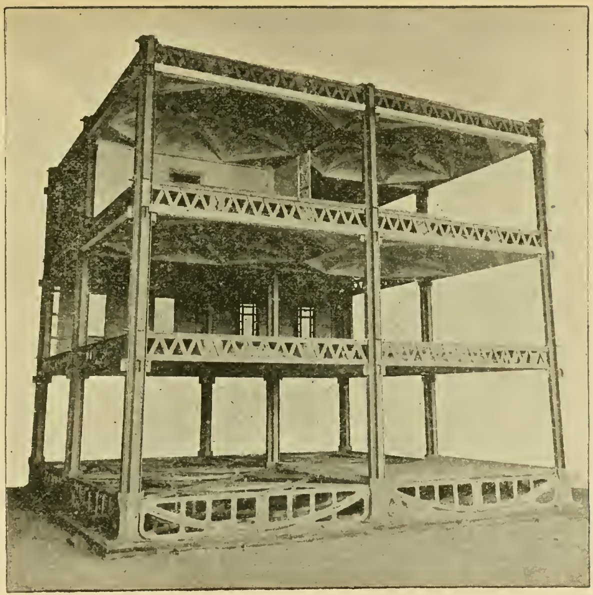
If the building will admit, columns may be used under all the ver-



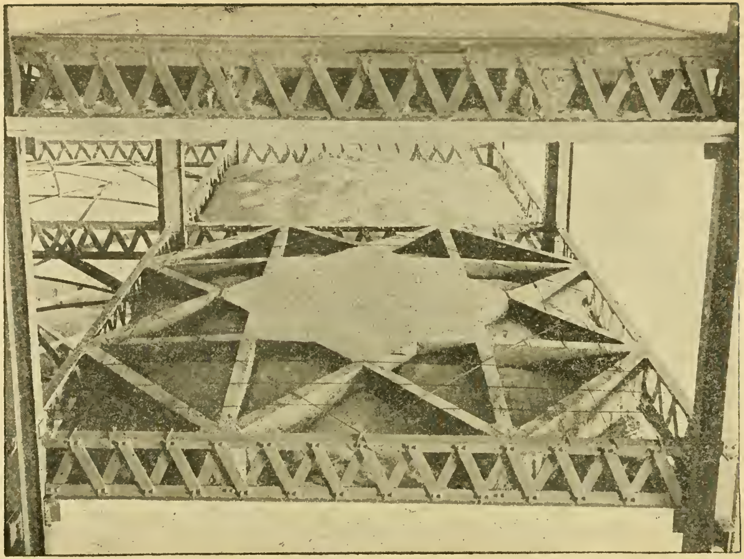
No. 1. Construction "F." Ceiling Decoration.



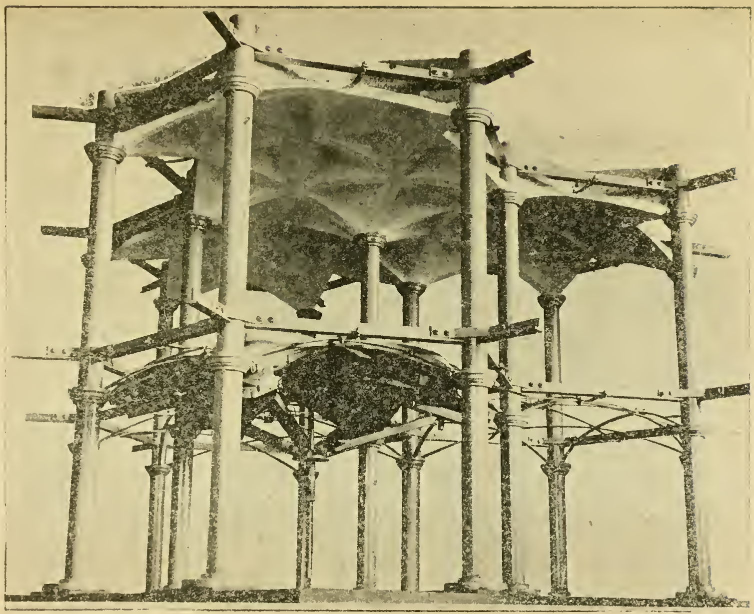
No. 2. Construction "F." Ceiling.



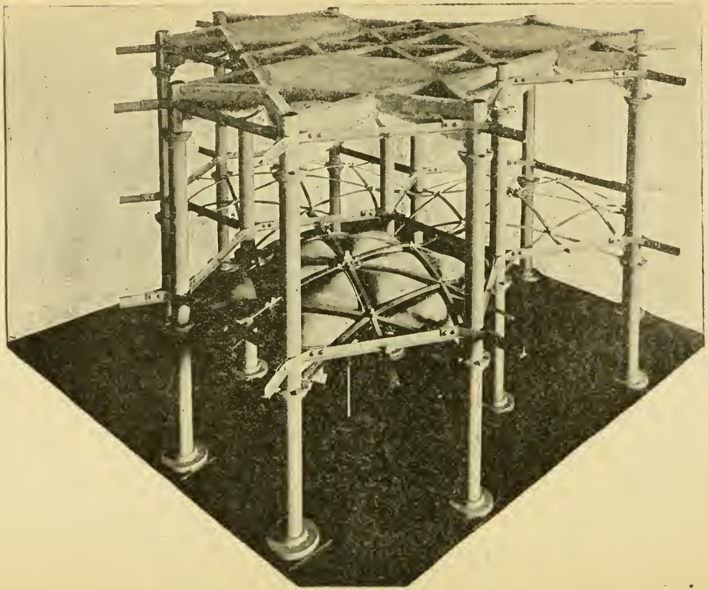
No. 3. Construction "F." Various stages of construction viewed from below. Floors divided into panels 25 ft. square by the girders. Inverted arches used for basement floor.



No. 4. Construction "F." Plaster domes in place on top of air cushions in farther panel. Cement ribs built up, center of panel filled in and wires stretched ready for the wire cloth in nearer panel.



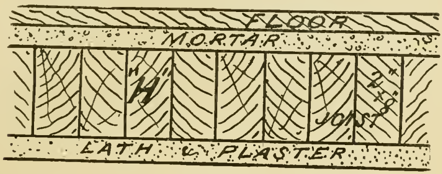
No. 5. Construction "F." Hexagon panels and floor carried without girders. Finished ceiling in upper story. Umbrella scaffoid in place. Supporting air cushions below.



No. 6. Construction "F." Same as No. 5, viewed from above.

tices of the octagon and the girders omitted altogether. I have a number of photographs of this construction which I would like to have the club examine. It will be seen that beside their strength and lightness that the ceilings possess great beauty.

"H." We come now to fire resisting or slow burning construction. The essential features of this are wooden columns, solid wooden beams and floor joist laid side by side. Partitions are made with porous terra-cotta blocks, or sometimes of studding filled in solid with brick work. Furrings are porous terra-cotta, or hollow brick laid in the



wall. The things which must be absolutely avoided in this construction are: Hollow spaces in floors, partitions, and furrings, through which fire can travel from one story to another, and cannot be reached by a stream of water.

It is well known that fire does very little more than char a solid timber of good size. Experiments have been made of subjecting 12″ × 12″ wooden posts to an intensely hot fire for a number of hours, and the results show that such a timber has very little to fear from an ordinary blaze. All wooden posts must be bored through the center and ventilated to prevent dry rot and checking.

Wooden beams built into walls must have an air space around the ends and so anchored to walls and secured to the iron plates on the columns that in the event of the burning and failure of any one section the ends of the beam can drop out without destroying the wall, or pulling down the adjoining sections. On the top of these girders the joists, 2″ × 8″ usually in size, are laid side by side. The wall ends rest upon a ledge corbelled out to receive them. Over the joist are nailed inch strips to level up for the floor and the space between them filled with mortar.

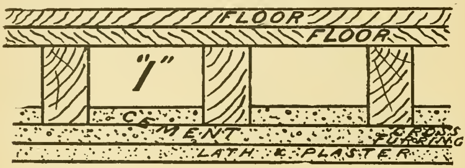
The underside of this floor and all girders and posts are covered with metal lath and plastered.

The weight of this floor is 39 lbs. to the square foot, and the Blackstone Building is an example of this class. In very high buildings wooden posts and girders become impracticable, and iron and steel must be used and protected in the most thorough manner.

"I." Another method of floor construction is to place the floor joist in an ordinary way 12″ or 16″ centers. On the bottom of them are nailed 1″ × 2½″ cross furring strips running in the opposite direction.

The ceilings are covered with metal lath nailed to the cross furring strips, and on top of this and between the joist is put 2″ of mortar.

When this is thoroughly dry, the ceiling is plastered in the usual manner. It is also wise to have a series of heavy metal hooks from



the metal lath up to some 3″ above the bottom of the joist. The floors in this construction are double, and have a layer of asbestos felt or water proof paper between.

The weight of this floor is 42 lbs. to the square foot, and the construction was used in the new Tracy Building at the corner of Superior and Seneca Streets.

I will close by laying before you a brief summary of the weights of the different constructions and their cost per square foot. I will also state that I never realized the difficulty of obtaining exact information until I endeavored to obtain part of my figures by mail. While a few of the items are not all that I could wish, they are all sufficiently accurate to give a good idea of the comparative cost of the different systems.

Of course the difference in the cost of the floors themselves is not so much a factor in the cost of a building as the difference in the expense of the columns and girders necessary to support them, and for that reason I endeavor to keep the weight as constantly before your eyes as the price.

Still in the single item of floors. A building like the Society of Savings contains 104,000 square feet of floor space, and the difference between what it now has, (construction "C"), and the least expensive of the fire pooof systems, (construction "F"), would be a saving of $87,420.00.

Add to this the amount saved in the supporting beams and posts and it will be seen that the time is well spent in devising the lighter construction.

PRICE TABLES PER SQUARE FOOT,

MATERIALS.	FIRE PROOF FLOORS.						FIRE RES'G FLOORS.			PARTITIONS AND FURRING.					
	"A" Brick Arch.	"B" Iron Arch.	"C" Hard T.-Cotta.	"D" Porous T.-Cotta.	"E" Economy.	"F" Paulson.	"H"	"I"	"K"	"C" Partition.	"D" Partition.	"C" Furring.	"D" Furring.	"K" Partition.	"K" Furring.
Iron Beams.	$1.17	$1.17	$ .98	$ .98	$ .68	$ .14	—	—	—	—	—	—	—	—	—
Bolts.	.05	.05	.05½	.05½	—	—	—	—	—	—	—	—	—	—	—
Arches.	.10	.05	.20½	.22	—	—	—	—	—	—	—	—	—	—	—
Concrete.	.05	.05	.03	.03	.30	.17	$ .01	$ .02½	—	—	—	—	—	—	—
Plaster P. Ceiling.	—	—	—	—	—	.08	—	—	—	—	—	—	—	—	—
Strips.	.00¾	.00¾	.00¾	.00¾	.00¾	.00¾	.00¾	—	—	—	—	—	—	—	—
Wire.	—	—	—	—	—	.02	—	—	—	—	—	—	—	—	—
Wire Cloth.	—	—	—	—	—	.01	—	—	—	—	—	—	—	—	—
Metal Lath.	—	—	—	—	—	—	.04¼	.04¼	—	—	—	—	—	—	—
Plastering.	.02¼	—	.02¼	.02¼	.02	—	.02¼	.02¼	$ .03	$ .04½	$ .04½	$ .02¼	$ .02¼	$ .06	$ .03
Joist.	—	—	—	—	—	—	.23	.05	.04¼	—	—	—	—	—	—
Cross Furring.	—	—	—	—	—	—	—	.02	—	—	—	—	—	—	—
Flooring.	.04¼	.04¾	.04¾	.04¼	.04¾	.04¾	.04¾	.07¼	.01¼	—	—	—	—	—	—
Paper.	—	—	—	—	—	—	—	.01	—	—	—	—	—	—	—
Painting.	—	.02	—	—	—	—	—	—	—	—	—	—	—	—	—
Bridging.	—	—	—	—	—	—	—	.01	.01	—	—	—	—	—	—
4" Tile	—	—	—	—	—	—	—	—	—	.11	.11	—	—	—	—
2" and 3" Tile.	—	—	—	—	—	—	—	—	—	—	—	.07½	.09	—	—
4" Wood Partition.	—	—	—	—	—	—	—	—	—	—	—	—	—	.05¼	—
1" Wood Furring	—	—	—	—	—	—	—	—	—	—	—	—	—	—	.04
	$1.44¼	$1.39½	$1.34¼	$1.36¼	$1.05½	$ .50½	$ .36	$ .25¾	$ .13	$ .15½	$ .15½	$ .09¾	$ .11¼	$ .11¼	$ .07

DESCRIPTION.	WEIGHT, LBS.	COST PER SQ. FOOT.
"A" Brick Arch. . . .	70	$1.44¼
"B" Iron Arch.	70	1.39⅜
"C" Hard Terra-cotta. .	40	1.34¼
"D" Porous Terra-cotta.	35	1.36¼
"E" Economy.	18	1.05½
"F" Paulson.	60	.50⅜
"H"	39	.36
"I"	42	.25¾
"K"	20	.13
"C" Partition.	35	.15⅜
"D" Partition.	33	.15½
"C" Furring.	19	.09¾
"D" Furring.	22	.11¼
"K" Partition.	25	.11¼
"K" Furring.	11¼	.07

DISCUSSION.

The President:—The paper is now open for discussion.

Mr. Gifford:—Mr. President I would like to ask Mr. Sabin if he figured that criss-cross construction, "F", at the same price of iron that he did the beams.

Mr. Sabin:—No, Sir. I figured for the beams $2^1/_{10}$ cents per lb. for the metal, and $^4/_{10}$ cent for the setting. For the bars I figured $^1/_8$ cent per lb.

Mr. Gifford:—I don't believe he could get that stuff delivered for much short of double what the beams cost. I had an idea it was figured up in some such way as that. I don't believe it is fair.

Mr. Richardson:—Mr. President; I would like to ask of Mr. Sabin, whether the patentee had figured out the strain that would come upon these irons, (Construction "F",) when they are loaded to the extent he expects them to be; and regarding the wire mesh construction, ("E",) that is put through the cement, as to what strain per inch of metal would be brought on that; also as to the duration of it, and whether it would rust. If it was rusty, the floor would be simply a concrete floor, and would have no greater strength than the breaking strain of the concrete would have. May be the cement would protect it, and may be it would be otherwise. An article that is patented in that way, and the guaranty of the patentee given, very often gives very high results.

Mr. Sabin:—In regard to these two constructions, they are comparatively new; I know very little about them. An engineer of Brooklyn, who is at the head of The Hecla Iron Works in Brooklyn, sent me material regarding it: it was first used by him in his own house; now they are using it in large buildings, warehouses, etc. Among the papers he sent me were a number of tables where he had figured out the

strain as it came on the iron, and it looked as though they were amply sufficient. In regard to the cement floor I don't know anything except what the agents claim. They are very unsatisfactory in their answers: they write about two pages and give the price of something I don't want at all. I proposed first thing that the wire would rust and the cement would help it; he said, "no, the cement would keep it from rusting." I had my doubts about it. I think, however, that the floor would be amply strong if the iron all rusted away. They also claim that the mixture they use for the concrete gives it a great degree of elasticity. These tests were made in Chicago, for the benefit of Jenney, and the letter which he writes was quite satisfactory. He said that the floor stood a deflection and came immediately back, and he thinks it is a very good floor.

Mr. Gobeille:—Take fast running machinery and it is necessary there should be considerable elasticity. Machines running 5,000 or 6,000 revolutions a minute on long arbors—like 24″ or 30″ arbors—with two or three bits on it, it requires something different than an absolutely solid floor. This construction, ("H",) if I look at it right, is similar to that which is advocated by Atkinson & Woodbury of Boston. They have presented some great advantages in this kind of construction. I think the rates are about one-half on the slow burning wood; they come on the ordinary all terra-cotta fire-proof building. The principal thing to be observed in slow-burning construction is, that all timber should have a hole through the entire length; it is difficult to get it, but it can be done. The next thing is to keep the wood covered, and the best covering, I think, is common whitewash. The great incendiary of this country is simply d-i-r-t, dirt; it starts all the fires; and if you can keep some covering between the wood and the dirt you have accomplished something. You will never keep all the dirt out; there will be one corner full of shavings and another full of waste, and the first thing you know you have a fire, and you think somebody got in and lit a pipe and set it on fire. I think it is a good plan to whitewash everything once a year, and then trust in the Lord and keep a good insurance on your place; and that is about as good a fire-proof construction as you can have.

I think that a very good compromise between wood and slow-burning construction, and the absolutely fire-proof construction would be to use iron for the main carrying portion for the columns and girders, and fill in between with this method. I find one great trouble in using heavy wooden beams for the main carrying portion, and that is dry rot. If they were painted with that whitewash the dry rot would not be so bad as if you paint it with three coats of paint.

Mr. Richardson:—I had a lower story painted with three coats of paint and the upper story whitewashed. After eight or ten years the

lower parts were rotten as usual, and the beams on the upper parts that had whitewash on them were sound. The three coats of paint had formed an impervious skin and the sap in the wood had fermented inside and formed some sort of rotting system that rotted the inside out. The other beams were exposed to the atmosphere and checked on the outside and inside sound. You could use cast iron columns and steel beams for the main carrying girders and fill in 2″ × 6″ and plaster, with the wire lath below; it would take quite a fire to do any damage to that building, and it would be much cheaper than the arches and iron beams the other way.

MR. COBURN:—One of the systems of construction uses plaster. Is it used next to the beam? You all know that if there is anything that is improper to use against iron work it is plaster. It is supposed that a good cement is one of the best preservatives of iron. I think we can depend on it, if we get a good coat of cement on the iron before it starts to rust. I think it would be better than paint. Of course, we are not always sure of the purity of the cement, there may be impurities in it. The idea of putting plaster directly on such work is the worst thing that can be done.

In regard to the latest use of terra-cotta, it can be made lighter than has been shown by the diagram by using a little higher beams than usual and making the skew back higher so the bottom part of the beams would be covered by the skew backs. The arch need not be the full depth of the beam in order to be sufficiently strong.

We are doing some work that way, and I think we have saved perhaps a quarter of the load.

MR. SABIN:—He don't propose to have the plaster come in contact with the iron work. At each side of the iron bar there is a board, and the cement beam is built on top of the iron and entirely incloses it before the rubber backs are put on, and then the plaster only touches the concrete.

MR. OSBORNE:—My impression is that the concrete preserves the iron. I would like to hear from Col. Smith on that.

COL. SMITH:—Mr. President; I haven't my ideas in shape to present them so they would be of interest. I came here for the purpose of being a good listener. At some other time I shall be glad to do what I can to contribute to the entertainment and information of the club.

MR. RICHARDSON:—Some years ago I read in the London *News*, that the English architects were coating their iron beams in a wash of lime to preserve them: taking slaked lime and washing the beams with that, and they found that it was a good preservative.

THE PRESIDENT:—Mr. Coburn made a suggestion that will help a good deal to preserve iron, and that is: be sure to preserve it before it

gets started to rust. It is out of the question to stop it after it has once started.

Mr. Richardson: Usually they oil iron beams before they are painted.

The President:—I have done that; personally I believe in it.

Mr. Richardson:—I have done that for the past year, and I think it is good.

The President:—I don't have much of a notion of doing any painting myself. I think that work, after it is built, the only thing is to immerse it,—give it a boiling, if necessary. Ordinarily I don't have much confidence in it.

Mr. Richardson:—I used red lead last year.

Mr. Bowler:—Last year we painted with this iron-clad paint, No. 22 or 24, and we used that kind of paint and used good oil, and I wondered why it would rust so quick. We have taken off the iron-clad and made a brick wall. I think iron-clad paint is not good to prevent rust. It was painted while the iron was new, on both sides; but it didn't last.

We have a great deal of sulphur in the atmosphere around our foundry, which must contribute largely towards rust; but I have lost faith in using iron-clad as a mixture with oil. I think a good coat of boiled oil is good without any mixture.

A WELDLESS CHAIN.

By Ludwig Herman, Member Civil Engineer's Club of Cleveland.

The common welded chain with oval links is well known. I have seen specimens of the same, 200 and some more than 400 years old, made precisely as chains are made today. It is almost as simple to make a chain of this kind as it is to make a cannon, and no doubt you all know how these are produced. You take a hole of the desired shape and dimensions, put a piece of suitable metal around it, and the cannon is finished.

There is but very little more trouble in making chains. The difficulty commences in using the same. Here we are apt to encounter unsuitable material, poor welds, burned iron, unequal pitch, excessive friction, rapid wear, unstable shape and, in the case of anchor chains or cables, the stud, the shackle and other objectionable features.

Recognizing the great importance of a thorough understanding of all the conditions under which chain is manufactured and used, the Board for Testing Iron, Steel and other Material appointed by the President of the U. S. in 1875, delegated this entire subject to a special com-

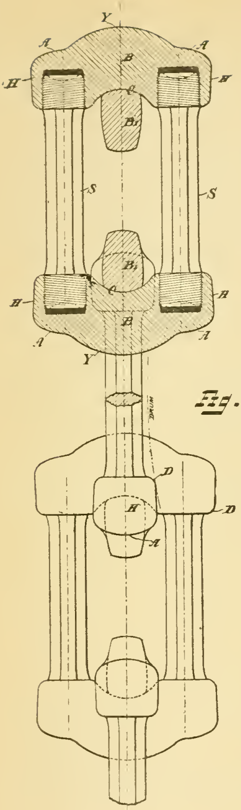


Fig. 2.

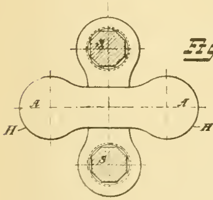


Fig. 3.

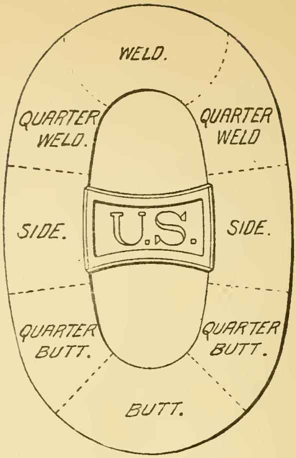


Fig. 1.

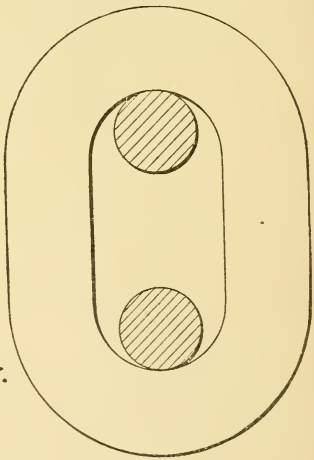


Fig. 4.

mittee. The very valuable report of this investigation and the results obtained thereby have assisted me materially in my labor. In the report referred to the chain link is divided into eight sections as shown in Fig. 1.

Out of 435 links tested by the committee,

217	links,	or 49.9 %	broke	at quarter weld,
116	"	" 26.7 %	"	through the weld,
65	"	" 14.9 %	"	at quarter but,
21	"	" 4.8 %	"	through the but, and
16	"	" 3.7 %	"	through the side.

This table proves that the quarter near weld and but is even weaker than the weld and but itself. The reason for this is found in the fact that while the amount of material is about uniform at all sections of the link the strains at the quarters are excessive.

The strains in each link vary from point to point throughout its entire shape; in the middle of the sides they are strictly tensile, at both ends bending, while the intermediate quarters are subjected to a complication of tensile, bending and shearing strains. By the introduction of the stud the strains are still further complicated.

To produce an ideal link the cross sections would have to vary from point to point so as to be proportioned to the various strains acting at each successive point.

To accomplish this end and at the same time do away with the uncertainty of the weld, also to correct some of the other objectionable features of the oval link chain, I produced the device that I shall present to your criticism tonight.

Each link of the chain shown in Figs. 2, 3 consists of four separable parts, two straight side-bars—S, S and two end pieces or yokes—Y, Y. The side-bars may be of any section though I prefer to make them octagonal to facilitate the assembling or separating of the links. Each bar has both ends enlarged and threaded, one with a right hand thread, the other with a left hand one. Each yoke consists of a center part B that we may call the beam. This is provided at each end with an enlargement called the head—H, H. Each head has a threaded cavity in which the screw ends of the side-bars are secured. The side-bars do not screw up against any shoulder, for this would produce initial strains in the thread.

At B_1, B_1, the beams of adjoining links are shown in cross-section. A chain made of links of this shape retains to the fullest measure the perfect flexibility of the ordinary chain at every joint. This flexibility is the reason why the old chain was never superseded to any extent by the many devices introduced for this purpose. Though each had certain advantages, all failed in this, the most desirable quality.

As in all chains, the load is transmitted from link to link at the cen-

ter of the yoke. The yoke in my link acts as a beam loaded in the middle and fixed at both ends. From here the strain passes by means of their screw ends into the side-bars. The strains in each part and at every point of the entire link can be determined with the utmost exactness, and so I am enabled to provide at each point the amount of material required and put it in the most desirable shape for the duty it has to perform.

The side-bars require a material of high tensile strength combined with considerable elasticity or high resilience; it must be tough and stand any amount of use and even abuse without serious injury.

For the yokes the material ought to be somewhat harder and more rigid. for here stiffness and the ability to resist abrasion is an additional requirement.

Having decided upon the material for the chain, I can proceed to determine the proportions of each part.

The ordinary chain is bought by the diameter of the bar whereof the link is made. For example, ½″, ¾″, or 1″ chain. This dimension does not give any information as to the strength of the respective chains, as the same size will, according to quality of material and workmanship, give a very wide range in the ultimate strength of the link. For instance, a link made of 1″ iron will, according to the standard of the U. S. Navy, have an average ultimate strength of 71,172 lbs.,

By Trautwines table,..................... 49,280 lbs.,
By test table of one chain-maker,.......... 68,200 lbs.,
By test table of another chain-maker,...... 52,660 lbs.,

and so on, each maker has his own standard, and as stated above the size of a chain does convey no information at all as to its quality, strength or pitch.

I propose to introduce my chain by numbers. These numbers will give all the information needed in selecting a chain for any given work. This I accomplish in the following manner: let the guaranteed ultimate strength of a chain in pounds divided by one thousand be equal to the number of the chain, which we may designate by letter N. Then,

$$1{,}000\ N = \text{Ultimate strength in lbs.}$$

For a factor of safety 5:

$$200\ N = \text{Safe load in lbs.}$$

$$\frac{N}{10} = \text{Safe load in net tons.}$$

$$\frac{N}{11.2} = \text{Safe load in gross tons.}$$

For a factor 4 it would then be:

$$250\ N = \text{Safe load in lbs.}$$

$$\frac{N}{8} = \text{Safe load in net tons.}$$

$$\frac{N}{8.96} = \text{Safe load in gross tons.}$$

For the standard pitch of the chain I intend to use this formula :

$$P = 0.5 \sqrt{N}$$

making probably also a short and a long pitch by the formulas :

Sh. $P = 0.45 \sqrt{N}$ and L. $P = 0.55 \sqrt{N}$ respectively.

But in replacing old chain I shall have to vary the pitch of my link to correspond to that of the respective chain. This I can readily accomplish by making the side-bars longer or shorter, as the case may be.

To show the application of these Nos. we will assume that an engineer is designing a 30 ton crane and intends to use for hoisting a six part chain; then each part of the chain will have to sustain 5 tons. Using the factor of safety 5, we have the formula:

$$\frac{N}{10} = \text{Safe load in net tons.}$$

In this case, $\frac{N}{10} = 5$ and $N = 50$.

It will be a No. 50 chain that he must use.

To determine the diameter of his chain wheels the pitch must be given. Now

Pitch $= 0.5 \sqrt{N}$ In this case,

$N = 50, \quad \sqrt{50} = 7.07$

Pitch $= 0.5 \times 7.07 = 3.535$ or $3^{17}/_{32}''$, as I shall use the nearest number of 32nds. of the inch for the pitch.

Should four be used as factor of safety, then

$$\frac{N}{8} = 5 \text{ tons, and } N = 40$$

A No. 40 chain would do. The pitch is then

$$0.5 \sqrt{40} = 0.5 \times 6.3246 = 3.1623, \text{ say } 3^{5}/_{32}''$$

and so with the other formulas.

A point often made in favor of the oval shape of chain links is that they possess considerable elasticity of form, if I may so call it, in contradistinction to elasticity of material. The ellipse under any stress will lengthen in direction of the great axis and shorten again when relieved. It is a fact generally recognized by engineers that this action is very destructive to the material and leads invariably to a rupture. To remedy this the stud has been introduced, especially in heavy chains. But while the stud stiffens each chain link effectively, it also introduces new complications of strains, and, as the U. S. Commission, referred to above, has clearly demonstrated, weakens the link and ought to be eliminated.

Of late pitch chain intended for hoisting machines is made with

straight sides as shown in Fig. 4. This remedies the objectionable elasticity of form to a considerable extent.

In my link I depend entirely on the elasticity of the material and make the yoke, the only part subjected to bending strains, purposely as stiff and rigid as possible. I am justified in this by the best practice in civil as well as mechanical engineering.

Take for instance, in bridge building the only instance where a curved tension member is employed is the cable of a suspension bridge; or the similar case of a curved bottom chord of some trusses. In all such structures bracing is introduced to counteract and eliminate the objectionable elasticity of form.

In mechanical engineering the only extensive application of this kind of elasticity aside from the oval chain link is found in the different shaped springs. These while very useful and in many places indispensable are not as reliable as other constructions and require generally frequent renewals.

The link under consideration will, under ordinary use, retain its shape and dimensions practically unaltered, a very desirable quality where the chain is employed in connection with sprocket wheels.

When this chain is used on a sprocket wheel, the sprockets come in contact with the surfaces A in Figs. 2, 3, while in the ordinary chain the contact takes place at a single line. The shape of the link at A is similar to the form of an involute tooth, facilitating thereby the ease of entering and leaving the wheel-pockets by the chain. On account of the enlarged surface where contact takes place between chain and sprocket at A, as well as between link and link at C, the wear and friction in this chain will be considerably less than in the older form.

Where my chain is used on a drum or sheave it will rest on the projections at D, D, thereby preventing the side-bar from coming in contact with the drum.

When chains are used for ship-cables the practice at present is to make the same in six to twenty lengths of 75 ft. each. These lengths are then connected to each other by means of shackles. The purpose of the shackle is to admit of dividing the chain quickly by removing a pin. Under certain conditions this becomes necessary in order to free the vessel from its anchor. A disadvantage of this arrangement is that the shackle, as well as the two preceding and two following links, are so much larger than the other links in the chain that they will not engage with the pockets of the chain wheels used.

In cables the links are usually provided with studs to prevent the entangling of the chains.

In my chain every link can be quickly separated by turning the side-bars and unscrewing the same. This is accomplished by a wrench designed especially for this purpose. By the same means I can readily

splice, lengthen or shorten the chain, remove or replace links and make a chain endless.

The shape of the yoke will effectively prevent the chain from becoming entangled, and as the side-bars are parallel I have no occasion to use a stud.

The several specimens here speak for themselves. Tests made at the Otis Steel Works, as well as those made at Cornell University, show that the ultimate strength of this chain will be from 97 to 100 per cent. of the strength of the two side-bars. All perfect links tested broke in the side-bars and show decided necking at the point of rupture, as also do the bars not actually broken but subjected to the ultimate strain only.

These links prove also that my chain will be considerably lighter than an ordinary chain of the same strength and pitch.

Here we have a number of models for different sizes of links. These models are used to verify the correct working of the links when connected in a chain.

In manufacturing this chain the side-pieces will be rolled in octagonal bars, of uniform section throughout. These bars are then cut to the desired length and their ends upset.

The yokes are produced from blanks by means of suitable dies in a drop-hammer or press. After annealing, both these pieces are placed into hoppers of an automatic machine invented by me, this will do all the machining, assembling and proving and deliver the chain in a continuous piece ready for use. A machine of this kind is now under construction.

DISCUSSION.

MR. RAWSON:—Mr. President, I would ask what is the cost of the manufacture of this chain?

MR. HERMAN:—We have no positive data as yet. From tests made, we expect that the machine now building will produce one link, complete and tested, in the chain ready for use, every minute.

MR. RITCHIE:—What is your object in using such high grade steel? Why not use soft steel?

MR. HERMAN:—For side-bars I intend to use steel that will stand 75,000 pounds with an elongation of 20 to 25 per cent. This same steel is used in thousands of car axles; the record of this steel in car axles is very satisfactory. The steel is tough and elastic, and can be had in any quantity according to specifications, a thing that you could never get in iron.

MR. RITCHIE:—I did not mean iron; I meant soft steel; what we call soft steel in bridge work. That would stand 56,000 pounds.

Mr. Herman:—Soft steel that will do for bridges is rather low in resilience: it is not the steel that ought to be used for chains. As there are no welds, I can use a grade of steel of high resilience. Prof. Thurston speaks in his work "The Materials of Engineering" of the very grade of steel that I use, and states that it should be used wherever a reliable material of high elasticity and resilience is needed.

Mr. Fuller:—Why do you use still stronger steel in the yokes?

Mr. Herman:—I want the yokes very stiff, and still tough, also able to resist abrasions.

Mr. Blunt:—I understood you to say these bars were not screwed to shoulders. I would ask how you determine the exact length of each link.

Mr. Herman:—The machine will cut the side-bars to an exact length, and give just so many threads to the inch. By turning them a certain number of times while they are being connected with the yokes, the pitch will be identical in all the links. Many have suggested that the side-bars ought to screw up against a shoulder, but in doing so, initial strains of an unknown quantity would be introduced in the thread, and any additional strain might strip the same.

Mr. Baker:—How do you arrive at the particular thread that you use on the links?

Mr. Herman:—The shape of this thread is not new; but it is the best for my purpose. Prof. Thurston some years ago made an elaborate series of tests on nuts and threads, and the conclusion he came to was that 40 to 45 per cent. of the standard depth of a nut would be entirely sufficient for strength. I have, in all my work, used authorities wherever I could find them. I have used records of reliable experiments freely. I make the nut deeper than 45 per cent.—about 75 per cent. of the usual depth. This is not on account of strength; it is on account of some other detail which has more reference to the manufacture than the using of the chain.

Mr. Porter:—Chains are subject to rough usage, wrenching, and sudden load. I would ask Mr. Herman what the effect is going to be on the strength of the link by cutting this thread—what effect the thread is going to have in regard to bending, as it will be in many cases of rough usage.

Mr. Herman:—The thread is proportioned much stronger than the side-bars. In determining the number of the chain we get the unit strain of that link. For instance: in No. 100 the side-bars are proportioned for 100,000 pounds. The thread, nut, yoke, and every other part in the link is made stronger; in some parts 20 per cent., in others even more, up to 75 per cent., and in the nut fully 100 per cent. additional. As stated in my paper, the strains acting in the quarters of the ordinary chain-link are complicated, and hard to determine. In my link the strains can be readily analyzed. The strain in the entire side-bar is

tensile, and in the beam of the yoke transverse: where the heads join the beam we have shearing strain. In the head and nut the strains are more complex, and under certain conditions may tend to split the nut. For this reason the nut is made twice as strong as its legitimate load would require.

Mr. Searles:—We will agree that this is a very interesting subject. It is a case in which we see the principles of modern engineering applied to a subject which, in itself, is very old, and which heretofore has been solved by rule of thumb. In many respects I think it commends itself as the outcome of a great deal of careful and scientific study, and as presented it seems as though it might be ultimately successful. At the same time I think it is our duty, and privilege as well, to criticize a new thing. If it has any defects it is better that they be found out early than late. The method of putting the links together is very ingenious indeed, and fully described in the paper. Each side-bar necessarily has a right and left screw so both ends of it may enter at the same time. Then, there being two of them, it is necessary that they should both enter at the same time; both bars must be screwed into both heads at the same time and the same amount. For that purpose a peculiar wrench is devised so that by the turning of one crank both bars will be screwed into both heads equally and at the same rate. It is very ingenious, and necessary to the perfection of the link.

But now these bars do not screw up to any definite point, nor are they seated against any shoulder. The amount of the number of turns is done by rule, and the work stops when a required number of turns has been given, not because there is a necessity to stop. What then prevents one of these bars from tending to turn a little? There is no pinching, each screw is loose in its own nut, and if on rough handling of the chain one of those bars is set out a little, and the other set in a little, then there is a cross-strain as between one bar and the other; one may act as a lock-nut to the other. When you come to put on strain, one takes the strain and relieves the other, and you get a side-motion, and your theory of parallel forces and direct tension falls to the ground.

Another point: tests, so far as made, are altogether those of precision, placed carefully into the testing machine and the strains applied in lines precisely parallel, and the bars straight. But place the cables out over a ship's side, and the anchor bends them as they come in. Will they not tear out these nuts which are so slight? These questions arose in my mind.

Mr. Herman:—The first question is about screwing up against a shoulder, and the control I have over it. I call Mr. Searles' attention to this: the work of man is unreliable. No matter how carefully a man works, he will make an error once in a while, sometimes a very serious one. A mechanical device with positive movements will make no er-

ror unless it breaks down entirely. I would a hundred times rather trust to the number of turns that a machine will make and then stop, than depend on any man I know, and his judgment about screwing up the side-bars. As regards the liability of a link being bent and throwing the nice calculation out of shape, my calculations are all based on ultimate rupture four to five times as high as any legitimate or even illegitimate strain that can get on my chain. I take advantage of the factor of safety. The factor of safety has sometimes been called a factor of ignorance. The factor is intended to provide for something that we do not know. We know a piece of steel will break under certain weight, and we know that if we stop within $^4/_5$ of that load we have a big margin to go on. · I take full possession of this margin. I have tried and proved that on account of the way this chain is connected there is no possibility of this undue strain coming onto it, not as much as in ordinary chains. The flexibility of the chain prevents these possible side-strains.

Mr. Searles:—My question was not answered. Granted that the link, as put together by the machine, is all right for experimenting; suppose we take hold of one of these bars with a wrench and leave the other stationary, pull this just as much as we dare. Then we have a compression strain on one end, resisted by the tensile strength on the other, and cross-strain in the head. Now the suggestion I made was that one of these side-bars might be turned accidently, not in the putting together, but afterwards in using. And we have the right to suppose that, since they are quite loose, and not set up to any head and not locked up to any nut; they are liable, through some abuse, to be turned, so one is in compression and other in tension. When you put on your maximum working strain one side has got to take it off, with a tendency to bend, with a possibility to rupture. That is the first idea.

In regard to the other: since the factor of safety is a factor of ignorance, why would it not be well to bend some links originally, and then try them?

Mr. Herman:—I did not have any difficulty with a single link about entering the rods and getting the links together as they ought to be: but in screwing together the two wrenches that we used had to be moved precisely alike. Just as soon as one got the slightest bit ahead of the other we had to stop and go back, and start over again. Four opposite threads in the same link make the most perfect locking device that can be found; it is absolutely safe against any accidental unscrewing.

As regards the possible excessive strain: say I take a 100,000 pound link. The bars are calculated for 100,000 pounds. The actual strain that will come upon them is one fifth of that, and I have 80,000 pounds to go on. By no possibility of wrenching can you produce a strain of 10,000 pounds in one bar in excess of the other. And whatever you can

possibly produce will have no practical effect. I had some bars purposely screwed up wrong. In the test one side-bar would stretch very little more than the other till they came to good bearings, and the link broke just the same as any other would.

As regards the bending of links purposely and then trying them—before I will go into the market with this chain I intend to get up a set of tests for chains which have, to my knowledge, never been made before. No chain has ever been tested for impact except in its material. There is no record of any impact test on chains.

The Chairman:—We have with us a celebrated visitor, Mr. Kirkavaag; we would like to hear from him.

Mr. Kirkavaag:—I would like to ask if these bars will not rust. I thought the thread you put in there would be rather delicate, and not very strong so you could produce a very heavy pull on it. I find a thread that is exposed will rust, and stick very tight.

Mr. Herman:—In the manufacture of the chain everything will be well lubricated. We use mineral oils for lubricants: these do not oxydize, and are a good protection. Chains, generally, are not allowed to go without grease, and consequently I expect that the chain will not rust fast. Another thing: I can galvanize my chain just as well as other chains are, if there is any danger of rust. By the application of a mixture of mineral oils and graphite, rusting can also be prevented.

Mr. Baker:—Do I understand there is no possibility of the side-bars turning, not even in the slightest degree, in yokes like these?

Mr. Herman:—Actual tests in putting the links together show that less than five degrees advance in one bar against the other would bring the whole proceeding to a stand-still.

Mr. Benjamin:—In using steel the material is so elastic that a slight difference of strain in the two side-bars of a link would disappear in a comparatively slight load. Probably any strain of that kind in cast iron would cause rupture, because the material is not elastic enough to equalize the strain; but in steel that would not be the case. I would ask how does the strength and the weight of this chain compare with other chains?

Mr. Herman:—For the same ultimate strength my chain is lighter, even as far down as this $^5/_{16}$ link. This $^5/_{16}$ will only vary a fraction from the weight of the ordinary chain of good quality. From this upward I find by weighing the links a considerable gain: in link No. 300 as high as 25 pounds a foot against the ordinary chains. I take links of equal pitch, and gain about 25 pounds a foot, or about 40 per cent. In No. 100 I gain over 3 pounds per foot against the government's best chain. The government standard pitch for a 1¼ inch link is 4½ inches. In pitch tables there is generally no agreement between one size and the other;

they are mostly arbitrary, and no law can be deducted which will hold good for all the sizes.

Mr. St. John:—How close do you think these threads ought to work?

Mr. Herman:—Just as any machine screw ought to be made, so that they screw in without any undue resistance. What is called a good fit.

Mr. Palmer:—You have answered Mr. Searles' question. But suppose they should back out one third of the way, which is possible?

Mr. Herman:—This is not possible. I can conceive of no cause that would unscrew one or both bars, no matter if they be loaded or not; the action of the four threads upon each other is a perfect lock.

Mr. St. John:—Unless you had some lock on your side-bars there is a possibility of their backing out. I understand that it is supposed to be a lock in itself. But suppose one should loosen a little, and the other should loosen a little, how are you going to answer that?

Mr. Herman:—I know from actual tests that if one bar is turned the least in advance of the other, it takes considerable force to loosen either of them again. To unscrew a link both bars must be turned with exactly the same speed and in opposite direction. This can not happen by any accident.

Mr. St. John:—You understand that a continual jarring will unscrew a nut?

Mr. Herman:—Not a self-locking device like this is.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

BOSTON SOCIETY OF CIVIL ENGINEERS.

February 15, 1893:—A regular meeting of the Society was held at its rooms, 36 Bromfield Street, Boston, at 7:40 o'clock P. M.

President Henry Manley in the chair, 65 members and 37 visitors present.

The record of the last meeting was read and approved.

Messrs. Roland N. Cutter, Frank B. French, Franklin B. Locke and Edwin A. Taylor were elected members of the Society.

The President announced the death of Joseph Coulson, a member of the Society, which occurred at Savannah, Ga., January, 22, 1893. The President appointed as a committee to prepare a memoir, R. A. Hale and F. S. Hart.

The President appointed F. W. Hodgdon and E. E. Pierce, the tellers to canvass the ballots for officers to be elected at the annual meeting.

The Secretary read a communication from Mr. C. J. H. Woodbury transmitting a copy of a paper read before the American Society of Mechanical Engineers by H. F. J. Porter, referring to the status of the Engineering Profession. The communication was referred to the Board of Government.

Vice-President W. E. McClintock was then introduced and gave a very interesting account of the work of the Mass. Highway Commission. At the conclusion of his talk there was thrown on the screen a large number of views illustrating the condition of the roads throughout the state.

Mr. E. W. Howe illustrated by lantern views the roads built in the Boston Parks and Mr. E. F. Foss of the Mass. Institute of Technology showed some excellent views of roads in Chicago and Buffalo.

A general discussion followed on road construction in which Messrs. Allen, Cutter, Howe, Locke, McClintock and Rice took part.

Adjourned. S. E. Tinkham, Secretary.

THE CIVIL ENGINEERS' CLUB OF CLEVELAND.

March 14th. 1893. The meeting was called to order by President Rice with 50 members present.

The records of the last meeting were read and approved. The President appointed Messrs. Culley and Ditton tellers to count the ballots.

The Annual Reports of the Secretary, Treasurer and Librarian were read and accepted. For the Programme committee, Mr. W. R. Warner read a report on The Progress of Mechanical Engineering during the past year, and Prof. E. P. Roberts read a similar report on The Progress of Electrical Engineering.

On motion of Prof. Benjamin a committee of three consisting of A. H. Porter, C. W. Wason and J. W. Langley, was appointed to confer with the Trustees of Case Library regarding better quarters in the new library building and to see if arrangements could not be made whereby the Electrical Club, the Chemical Club and the Architect's Club should use the same rooms. It was understood that this committee should hold over during next year. Mr. Hyde introduced the following resolution and moved its adoption:

"*Resolved.* That the Civil Engineer's Club of Cleveland, deem it unwise, to deviate from the custom it has observed since its organization, of excluding from the Annual Banquet wines or other intoxicating liquors; and respectfully request the banquet committee to conform to said custom at the Annual Banquet to be given on the 28th inst. at The Hollenden."

It was discussed by Messrs. Hyde, Ritchie, Rice, Searles, Warner, Culley, Herman, Roberts, Gobeille, Benjamin, Baker, Howe, Porter, Langley and Walker. Mr. Searles moved as an amendment to the motion that the adoption of the resolution be referred to letter ballot and the result communicated by the Secretary to the committee as soon as possible. The amendment and the resolution as amended were carried.

The report of the tellers showed that Windsor Thomas White, Frederic John Falding, Nathaniel B. Dare and John B. Davis had been elected active members and Walter W. LaChance and Joseph Wellington Willard, Associate Members of the Club and that the following officers had been elected for the coming year:

President, A. H. Porter; Vice-President, C. S. Howe; Secretary, F. C. Osborn; Treasurer, C. P. Leland; Librarian, C. H. Benjamin; First Director, C. W. Wason; Second Director, James Ritchie.

On motion of Mr. Searles a vote of thanks was extended to the retiring officers for their efforts during the year in behalf of the Club.

President Rice then read his annual address on the subject, "The Mission of a Local Civil Engineer's Society."

Adjourned. CHAS. S. HOWE, Secretary.

ANNUAL REPORT OF SECRETARY.

To the President and Members of the Civil Engineer's Club of Cleveland, O.

The past year has been one of general prosperity for the Club. At the beginning of the year the membership consisted of 5 Honorary, 9 Corresponding, 8 Associate, and 142 Active Members, a total of 164. During the year 5 Associate and 25 Active Members have joined; two members have died, four have resigned and six have been suspended for non-payment of dues. The membership consists at present of 5 Honorary, 9 Corresponding, 13 Associate and 155 Active Members or a total of 182.

The membership is made up as follows:

Civil Engineers	80
Mechanical Engineers	43
Electrical Engineers	6
Sanitary Engineers	1
Architects	10
Scientists	13
Business Men	29

The larger part of the 29 Business Men are engineers but these figures have been compiled from the last Annual Register which gives their present occupation and not their profession. During the first year of its exis-

tence the club enrolled 83 members. Since then the members joining each year has been as follows:

1881—24	1884—18	1887— 7	1890—22
1882—24	1885—11	1888— 3	1891—15
1883—24	1886— 9	1889—21	1892—30

These figures indicate a strong healthy growth but there is opportunity for greater growth in the future. The Chicago Club has about 425 members, the Boston Club over 300 and the Pittsburgh and Philadelphia Clubs are larger than these. There are at least 150 engineers in Cleveland who do not belong to this Society and a strong effort should be made to bring them in. According to our Constitution an Associate Member "must be qualified by his business relations and practical experience to co-operate with engineers in the advancement of professional knowledge."

Cleveland is the center of manufacturing, railroad and mining interests and our associate membership should be largely increased from the business men engaged in these branches of industry. In ten years the membership of the Club ought to reach 1000.

With a membership of 500 we could build a club-house which should not only be completely equipped as a club home but should contain the larger part of the engineering offices of the city.

There have been 10 regular meetings besides the annual meeting and our special meeting held during the year with an average attendance of 31. The Annual Banquet held March 15th, 1892 was attended by 180 members and guests. The Annual Picnic on July 20th was attended by 80 members and guests. Eleven papers have been read before the Club, the titles of which are as follows:—

Apr. 12-92. "Astronomical Spectroscopy." Dr. Dayton C. Miller.

May 10-92. "Whither is our Architecture Tending?" C. W. Hopkinson.

July 12-92. "A Mathematical Discussion of Some Census Reports, with Special Application to the Population of Cleveland Past and Future." Dr. C. S. Howe.

Sept. 12-92. "Some Experiments on the Effects of Punching on Soft Steel." Prof. C. H. Benjamin.

Oct. 11-92. "Historical Sketch of Storage Batteries." C. F. Uebelacker.

Nov. 8-92. "Weighing Gases." Dr. Morley.

Dec. 13-92. "Cross-Ties on Railroad Bridges." James Ritchie.

Dec. 13-92. "Cross-Ties on Railroad Bridges." Robert Gillham, C. E. of Kansas City, Mo.

Dec. 13-92. Fire Resisting Construction." W. W. Sabin.

Jan. 10-93. "Certain Physical Properties of Steel as related to its Composition." Dr. John W. Langley.

Feb. 14-93. "A Weldless Chain." L. Herman.

Nearly all of these papers have been published in the JOURNAL which has appeared with a good deal of regular irregularity through the year.

An amendment to the Constitution relating to the Exchange of Members was adopted at the December meeting.

While the report of the Treasurer shows a small balance on hand there are bills to the amount of $70.00 or more which have not yet been presented. If these had been paid there would be a deficit instead of a balance. The annual dues are $8 for Active Members. Out of this the Club pays $3 for the JOURNAL, $1 to Case Library and $1 for Certificate of Membership. This leaves only $3 per member—a sum too small to meet the run-

ning expenses. The annual dues should be increased to $10 early in the coming year or the expenses of the Club must be cut down.

Respectfully submitted,

CHAS. S. HOWE, Secretary.

TREASURER'S ANNUAL REPORT.

To the President and Members of the Civil Engineer's Club of Cleveland.

RECEIPTS.

Balance on hand March 8th 1892		$ 97.30
Received from dues		1096.70
Total		$ 1194.00

DISBURSEMENTS.

Refunded Ex-Pres. Gobeille by vote of Club		$ 55.40
Journal, 4 Quarters		497.00
Case Library Rent		75.00
Case Library Dues		136.00
Printing and Stationary		179.78
Postage stamps and envelopes		79.90
Stenographer and transcribing		48.90
Clerk-hire, Secretary		28.86
Collector, Treasurer		11.70
Seal		9.50
Tributes to the dead { Ex-Pres. Whitelaw	56.50	
Tributes to the dead { Zenos King	5.00	61.50
Cady Staley fee as delegate, International Congress Internal Navigation		5.15
Total		$ 1188.69
Balance on hand		5.31

PERMANENT FUND.

34 Initiation Fees, at $5 each	$ 170.00
Interest to Jan 1, 1893	4.05
In Society for Savings	$ 174.05

WORLD'S COLUMBIAN EXPOSITION FUND.

Pledges from 91 members	$ 254.50

Respectfully submitted,

Cleveland March 7th. 1893. C. P. LELAND, Treasurer.

REPORT OF LIBRARIAN.

To the President and Members of the Civil Engineers' Club of Cleveland.

I cannot make this report just what I desired to make it, as I had expected to incorporate a report from Mr. Orr, the Librarian of Case Library, on the number of scientific books which have been added there during the past year, and on other improvements which have been made to render the Case Library more convenient and more valuable to members of the engineering professions.

I can however say that many new scientific works have been placed on the shelves of the library and that Mr. Orr stands ready to procure others as members of the club may indicate that they are needed. In the adjoining room may be found a very complete file of indexes to engineering periodicals while the bound volumes of the periodicals themselves are so classified and indexed as to be readily found. Personally I regard this as the most important feature of the library from an engineering standpoint.

I am glad to say that there has been a more extended use of the Case Library facilities by members of the Club during the past year, than heretofore. The books belonging to the Club were turned over to the Case

Library for safe keeping a year ago, and are now indexed, catalogued and shelved, and are accessible to members of the Club at any time. There have been no accessions to the Club Library during the year, except copies of proceedings and transactions of societies, and a few pamphlets.

I understand that at the present time plans are being presented for a remodeling of this building, and would suggest that steps be taken at once by the club to present to the Trustees of Case Library our requirements in the matter of rooms, and also to determine in what way we may join with other technical clubs of the city in the use of such rooms.

Respectfully submitted,

C. H. Benjamin, Librarian.

MONTANA SOCIETY OF CIVIL ENGINEERS.

March 11th., 1893. The regular monthly meeting of the Montana Society of Civil Engineers was held at the office of Messrs. Sizer & Keerl, Room 13 of the Atlas Block, Saturday evening, March 11th. 1893 at 7:30 o'clock.

Present: Messrs. Haven, Keerl, Wheeler, McNeill, Foss, Cumming, Herron, Ryon and four visitors.

Meeting called to order with President Haven in the chair. In the absence of the Secretary, Mr. Keerl read a circular from the department of agriculture on the effect of tapping for turpentine on long leaf pine.

A report was received from Mr. Keerl who was appointed a committee of one to secure a paper for the next meeting of the Society, stating that Mr. Cumming had promised to submit a paper on the West Gallatin Irrigating Canal at said meeting.

The Secretary having arrived the minutes of the last meeting and also of the Annual meeting were read and approved.

A report was received from the Committee appointed at the Annual meeting to prepare and submit to the Legislature a bill regulating the compensation of County surveyors, stating that the Committee met and prepared a bill, but that the same was never presented to the Legislature.

On motion of Mr. Foss said Committee was continued and requested to report the bill prepared to the Society at its next meeting.

An application for membership was received from Albert Moog, and on motion of Mr. Keerl was referred to the Trustees of the Society.

The President appointed Messrs. Keerl, Herron and Foss as the Committee on Library; and Mr. Ryon as Committee on Membership.

A communication was received from Mr. Darling severing his connection with the Society. and on motion of Mr. Foss, Mr. Darling was released from all dues since January first last.

The proposed amendment to the constitution of the Society submitted at the Annual Meeting was read and the Secretary instructed to send out ballots to the members that the same might be voted upon.

The Secretary reported the receipt of a letter from Mr. Augustus Knudsen accompanied by a little book entitled, "Triangular surveys from Single Station."

A communication was received from Mr. Donovan asking that he be allowed to withdraw from active membership in the Society and become an associate member, which request was granted.

Mr. E. H. Beckler being unable to be present, his paper entitled "Reconnaissance and Location of the Pacific Extension of the Great Northern

Railway Line from the East borders of Washington to Puget Sound," was read by the Secretary, Mr. Foss.

No further business offering the Society thereupon adjourned.

G. O. Foss, Secretary.

ENGINEERS' CLUB OF ST. LOUIS.

379TH. MEETING, MARCH 15, 1893. The club met at 8 p. m., at the club rooms, President Moore in the chair, and thirty-three members and three visitors present.

The minutes of the 378th meeting were read and approved.

The Executive Committee reported the doings of their 142nd meeting.

The resignation of Mr. Geo. H. Pegram as a director of the club, owing to absence from the city, was announced,

On motion, Mr. Edward Flad was nominated to fill the vacancy.

A letter from Mr Corthell was read, announcing the expected visit of a party of members of the French Society of Civil Engineers during the coming summer, and suggesting a visit to St. Louis. On motion, it was decided that Mr. Corthell be notified that the club would take great pleasure in receiving the party and doing what they could to entertain them.

Mr. Crosby called attention to the fact that books had been taken from the library without leaving the proper receipts.

Mr. Robert Moore then read the paper of the evening on "Some Notes on European Railways." By means of a chart, the mileage, cost, receipts, expenses, etc., of the railroads of the world were clearly shown. The cost per mile was highest in Great Britain—$212,220—and lowest in Sweden—$29,100. The interest on capital was: 5·2 per cent. in India, 5·1 per cent. in Germany, 4·1 per cent. in Great Britain, ·3·1 per cent. in the United States and 1·7 per cent. in Canada. The track and chair fastenings were illustrated by a number of photographs. This method gave a steadier track than the usual American method of using spikes only. A number of fine photographs showed the English engines and cars. The high cost of the English roads was shown to be largely due to the expensive bridges, terminals, etc. A marked feature of the English roads was rapid handling and delivery of freight, freight received at London during the afternoon being delivered at any point the next morning. In Switzerland and Germany the metal ties are being largely introduced.

Discussion followed by Messrs. Kinealy, Schaub, Johnson, Hermann, Colby.

Adjourned. ARTHUR THACHER, Secretary.

CIVIL ENGINEERS' SOCIETY OF ST. PAUL.

APRIL 3RD. 1893. Regular monthly meeting of the Civil Engineer's Society of St. Paul, was held Monday, April 3rd. 1893.

President Wilson called the meeting to order shortly after 8 p. m. 11 members and 23 visitors including a number of ladies were present to listen to Mr. Estabrook's comprehensive paper on the Isthmus Canals and their Relation to a Deep Waterway between the Great Lakes and the Atlantic Seaboard at New York. After the approval of the minutes of the previous meeting the following Amendment to the Constitution proposed March 6, was unanimously adopted.

ARTICLE XXIV.

Any member of any other Society of the Association of Engineering Societies in good standing may become a member of this Society when duly elected as described in Article 14 without paying the initiation fee and with a release from the annual dues for such period not over one year, as he may show by certificate he has paid in advance in the Society from which he comes.

The Treasurer was authorized to remit the balance of the Society's quota ($35) to the Treasurer of the Engineering Congress Auxiliary of the World's Columbian Exposition.

Mr. Estabrook's paper followed. He gave a history and description fully illustrated by maps, of the Suez, Panama, Nicaragua and Erie Canals. He touched lightly in his exhaustive tables of statistics and closed with the expression of some broad views on the canal subject. On motion of Mr. Woodman the thanks of the Society were voted to Mr. Estabrook and he was requested to prepare his paper for publication in the JOURNAL

C. L. ANNAN, Secretary.

WESTERN SOCIETY OF ENGINEERS.

300TH. MEETING, MARCH 1ST., 1893. The 300th., meeting of the Society was held at the rooms of the Central Traffic Association, The Rookery, on Wednesday, March 1, 1893, at 8 p. m. President Robert W. Hunt, in the chair and over 40 members and guests present.

The reading of the minutes of the last meeting was dispensed with, according to custom, the report having been printed and distributed.

The President called for the report of the Finance Committee, appointed at the last meeting of the Society, and Mr. John Lundie, for that committee, read the report. •

A general discussion followed the reading of the Report of the Committee and the resolution of the Board of Directors, resulting in a resolution calling for a special meeting to discuss the whole question, to be held March 15.

The Secretary reported, for the Board of Directors, the following gentlemen elected to membership: Charles B. Stowell, George David Stonestreet, Melville S. Hawkins.

The following applications were filed; W. J. Gillingham, Frank Morse Button, Peter Mogensen.

"Memorials" of Roswell B. Mason, and K. F. Booth, prepared by committees appointed for that duty, were read and ordered printed in the JOURNAL.

A paper presented by Mr. J. L. Van Ornum, on "A Reduction Formula for Stadia Leveling," together with a discussion by Prof. I. O. Baker, were read by the Secretary.

Owing to the sickness of the author, Mr. W. W. Salmon, his paper on "The Relation of Railway Signaling to Train Accidents," was also read by the Secretary.

Mr. Faust, of Baltimore was introduced to the Society, and explained his idea in regard to doing away with the grade crossing evil. The general scheme proposed is to raise the roadbed some 8 feet, and at each street intersection to divert such street so that it shall run parallel to the railroad but on descending grade in each direction, and then pass under the roadbed in the middle of each block, or at other determined intervals.

Adjourned. JOHN W. WESTON, Secretary.

ENGINEERS' CLUB OF KANSAS CITY.

February 13th, 1893. At the regular meeting of the Engineer's Club of Kansas City held on Feb. 13, the following officers were elected.

President, Robert Gillham; First Vice-President, John Donnelly; Second Vice-President, D. W. Pike; Directors, F. E. Sickels; J. A. L. Waddell and F. W. Tuttle; Secretary and Treasurer, Waterman Stone; Librarian, John F. Sickels; Representative to Eng. Socs, J. A. L. Waddell.

Mr. A. J. Mason read a paper on "Recent Improvements in Trench Excavations."

The following Amendment to the Constitution has been passed: "*Resolved*, That Article 2 of the Constitution be amended by the addition of the following Section:

"Section 4.—*Exchange of Members.*—Any member of any other Society in the Association of Engineering Societies, in good standing, may become a member of this Club, when duly elected as described in Art. 3, without paying the initiation fee, and with a release from the annual dues for such period, not over one year, as he may show by certificate he has paid in advance to the Society from which he comes."

Waterman Stone, Secretary.

ASSOCIATION OF ENGINEERING SOCIETIES.

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This Association, as a body, is not responsible for the subject matter of any Society or for statements or opinions of any of its members.

DEEP WATER FROM THE GREAT LAKES TO THE OCEAN.

BY L. E. COOLEY, MEMBER WESTERN SOCIETY OF ENGINEERS.

[February 1, 1893.*]

When I made a promise to speak on this question I did not anticipate the demands that would be made upon me. At that time I desired to speak upon this subject, because I had been asked to co-operate with various parties around the lakes in a convention at Washington, with a view of urging upon Congress the necessary surveys for a deep water connection from the Great Lakes to the Ocean. The convention has been held—I was not able to attend—and, I believe, Congress will order the necessary surveys by all possible routes from the lakes to the ocean. I have not prepared a formal paper. The technical questions were laid before the Society some two years ago, and I doubt the wisdom of additional discussion in that line until we have the results of these further surveys and observations.

But I do think it is wise to keep the general facts before the engineers of the West, because on the West will depend the energy and enterprise to put this project through, and until the West grows to sufficient strength it will not be carried out.

The points in connection with the matter which are of present interest, and which have grown in prominence in the last ten years, are based largely on the magnitude of lake commerce and the relation of water-borne commerce to rail. Some of you will remember Proctor Knott's famous speech on Duluth, something over twenty-two years ago, in which he characterized Duluth as "The Zenith City of the

* Mr. Cooley's remarks were extemporaneous and were afterwards revised from the stenographic notes.

Unsalted Seas." He made that speech when Duluth existed only on a map and in the imagination of its projectors, but Duluth has outgrown all the jibes of Proctor Knott. The commerce in and out of Lake Superior at that time was about one-half million tons; to-day it is over ten million tons, or greatly in excess of that going through the Suez Canal, and more than the estimates made of the commerce of the Nicaragua Canal when completed. When you come out of Lake Superior into the lower lakes and to the Detroit River, you have there a commerce, that as near as I can estimate, is about equal to the total commerce going through the Straits of Gibraltar into and out of the Mediterranean; in other words, the commerce of Lake Superior is about one-third of this total, and the commerce, principally of Lake Michigan, is the other two-thirds. We have here at Chicago a commerce exceeding that of Lake Superior, and about two-thirds that at Liverpool. These statements give you some idea of the commercial value of the great lakes and of Chicago's relations thereto.

In Porter's census statistics for 1890 the commerce of the great lakes is put down at 22.6 per cent. of the ton mileage of all the railways in the United States. I took the trouble to add to that the commerce of the Erie Canal and the Hudson River, and the Welland Canal, St. Lawrence River, which constitute the seaboard connections by water, and the aggregate amounts to about 30 per cent. of the total ton mileage by rail of the United States. Now, take the amount of shipping owned and in use on the lakes and their seaboard connections, in use practically for only seven months, and add to this the amount of shipping in use on the Atlantic, Gulf and Pacific coasts and the interior rivers, all of which is active for the greater part of the year; then, if the lake marine can be taken as a criterion for all water-borne commerce, more tons are carried a mile by water in this country than by rail. These are facts not generally known to the public.

Of course, there is a reason for all things. This commerce has grown enormously, and this growth is continuing. Our lake commerce has grown so great because of its cheapness as compared with rail. In the season of navigation more tons go out of Chicago eastward every week by water than by rail. A large proportion of the fleet pro rate with the railways at Erie, Cleveland and Buffalo. In this arrangement the rate by boat per ton mile is about one-fifth to one-sixth that of the connecting railways. Our longest lake routes are about 900 to 1,000 miles—900 miles from Buffalo to Chicago 1,000 miles from Buffalo to Duluth. The rate on grain has run in the vicinity of 60 cents per ton in recent years. The return on coal has been from 40 to 50 cents and to Duluth as low as 25 cents, or less than you can get it shoveled from the gutter across the sidewalk to the

coalhole. You, who are railroad men, know what that means. The general traffic of the lakes costs about one mill per ton mile on the longer routes, and I believe the average for all ports and all traffic is about a mill and a quarter, and the rail charge is several times this rate, as I have stated.

All this commerce is conducted upon a depth not exceeding sixteen feet of water, and in vessels which range in maximum capacity from 3,000 to 3,500 tons. A movement has been on foot for several years—it culminated in the Detroit waterway convention a year ago—for twenty feet of water around the great lakes. The new lock at the outlet of Lake Superior is now building on this basis and is well along toward completion. Last year Congress appropriated sufficient money and the contracts are let, so that in the course of a very few years the sixteen feet of water through the connecting channels of the great lakes will be increased to twenty feet. When that time comes our lake boats will carry over 50 per cent. more for practically the same cost per trip. In place of 3,000 to 3,500 tons you will have a maximum capacity of 4,500 to 5,000 tons between lake ports. I do not believe, as a matter of economy, in transportation about the lakes on these short routes of 900 to 1,000 miles, which are the maximum routes at present, that it would ever pay to deepen the lakes further. The time requisite to load and unload the heavier vessel becomes such a large item that the limit will have been reached so far as ordinary lake routes are concerned. But on the other hand, should we extend the lake connection to the seaboard, then it is a matter of serious consideration whether twenty feet is not merely a stage in development.

I will consider the matter for a moment on the basis of twenty feet. The route which is cheapest, no doubt, is by the St. Lawrence, but the St. Lawrence takes us down to the Canadian seaboard, not to the American seaboard, and when you consider the really small proportion of foreign traffic, of the movement from the interior to foreign ports as compared to that to the American seaboard, it does not meet the requirement. A route to the sea to meet the needs of the West must reach the American seaboard cities, which are the great consuming points, and it has become a well-settled truth, you may say, that wherever the maximum domestic consumption exists, by that line will the road extend to foreign ports. So a route for the West that would only give us an outlet by the St. Lawrence would fail of a larger part of its purpose, but a route down the St. Lawrence and leading into Lake Champlain and by Lake Champlain to the Hudson, would reach the American seaboard cities, and would be a route following around by all the lakes, and using all the deep water, cheaper than any other, costing less money than any other, and on which a boat could set out from Chicago and make a trip to New York quicker than by

any other; in fact, quicker than on an airline canal on account of the large proportion of deep water throughout the route. The distance from Chicago to New York bay by airline is not over 700 miles, by the Lake Shore and New York Central railway 982 miles, by the nearest possible ship canal route about 1,400 miles, and by the route mentioned 1,640 miles. Such a route would pass through Canadian territory just north of the State of New York for sixty to seventy miles, and it should be within the resources of diplomacy to acquire that little strip of territory, of less than a thousand square miles, for both an American and international route. I have given much consideration to the matter at one time and another, and I find that as compared to other routes the proportion of canal and river improvement is very small, and I estimate that twenty feet of water can be carried from Chicago to the American seaboard by this line for one hundred million dollars. That is between one-fifth and one-sixth of the capital represented by the Vanderbilt system of railways. The great lakes, with their arms and extensions, reach this interior country very much as does the Vanderbilt system of roads, and if any comparison is legitimate, the question of the relative importance of the two factors in the development of the country might be raised. You cannot, however, divorce them or compare them, because each is supplemental to the other. Railroad men have learned that railway properties in apparent competition with water, are those which are paying dividends, and not those which are running outside of this so-called competition.

I have made some estimates in regard to the cost of traffic with the American seaboard in the event of such a route being opened. The long distance traffic between Chicago and Buffalo on bulk freight may be taken at 60 cents a ton, and the rate is usually less on return cargo. One of the line steamers between Chicago and Buffalo will make the round trip in ten days, and a round trip could be made between Chicago and the seaboard at New York, Boston and Philadelphia in about sixteen days, and the charge from lake points to seaboard points should be about $1 per ton. The rail rate is about $4.80 for special freight, and for a haul which is not much over half the distance of the water route. On ordinary freight, the time will be very much the same by water as by rail; in other words, you can deliver freight in about one week.

As before remarked, if this route is to stop at the seaboard, twenty feet of water would probably be economical and sufficient, but a route that goes to the seaboard necessarily goes beyond, and the question arises as to the policy of attempting a greater depth. An ultimate depth of twenty-six feet is feasible about the great lakes. Up to twenty-four feet no extraordinary difficulties are presented, but further increase becomes a matter of serious moment. The present

cost of a policy which will make permanent structures, as locks, conform to a depth of twenty-six feet, leaving channels and canal prisms for subsequent deepening and enlargement, is nominal, and in future you can go to the limit, according to your pocketbook and your patriotism and the demand of commerce, all of which must harmonize for actual achievements. I am willing to admit that should twenty-six feet be carried no farther than Lake Ontario, or be confined to the lake system, that it is doubtful whether the advantage would repay the extra cost, as twenty feet seems well adapted to the traffic, and perhaps to routes extending even to local seaboard points, but beyond that, to remote seaboard points and to foreign ports, a larger depth is necessary, if transhipment is to be avoided. Except on special routes, the great business of the world is done on twenty-six feet or less. The largest ocean tramps carry inside of twenty-six feet, and many of them run eighteen to twenty-two feet, such as visit the South American ports and the West Indies and to the miscellaneous commercial harbors of the world; so that depth would admit the entire class of ocean tramps, which does the real general commerce of the world, to come into the lakes. Were that permitted, I feel assured the traffic between Chicago and European ports could be carried on inside of $2 per ton.

Suppose for the present that we consider deep water to the seaboard as somewhat remote and take up the matter on the basis of the Niagara Ship Canal alone, then the question arises as to the utility of connecting Lake Ontario, which is almost as detached a lake as Lake Champlain, for the purposes of commerce. The commerce of the lakes in reality is very largely confined to the four lakes—Superior, Michigan, Huron and Erie. Ontario would add another lake, or one-fourth to the total area of marine movement and give longer routes and better economy. It reaches certain great resources in Western New York in iron mines, is closer to the anthracite coal fields, which would furnish valuable return cargoes, and reaches closer to New England points at Ogdensburg, and New England is a great trader with the food regions of the West. I believe that to add Lake Ontario to the system, even though it might never be possible to reach the Atlantic, would be a justifiable measure.

Suppose that a rate of one dollar per ton should prevail from the lake region to the seaboard for seven months per year, what would be the effect on the internal movements of this country. I believe that it would turn railway traffic toward the great lakes; in other words, it would virtually extend the seaboard into the heart of the country, and that of itself will necessarily draw wealth to our lake shores.

What could you afford to pay for it? The railway investment in the State of Illinois represents $800,000,000. The cost of opening this

great Lake Michigan to ocean traffic is a hundred million dollars, and Illinois alone, on account of her strategic position in the heart of the continent, could afford to do it, rather than to not have it done ; in fact, we could well afford to sacrifice half our railway system if it were necessary, to accomplish the work.

An important economic consideration is the fact that our enormous lake marine is only employed seven months. What would be the added wealth if our marine could be turned loose for the five idle months, if this great shipping interest could be turned into ocean trade —do a tramp business, and keep the sailors employed during the five months. That of itself is very worthy of consideration, and if these vessels could be so employed, and the crews worked steadily, I do not doubt but that the present low rates now enjoyed on the lakes would be greatly reduced from that one cause alone. There would be larger profits, which could be shared with the forwarder in reduced rates.

On the other hand,—a favorite and pet thought of mine—suppose that you could extend this deep water channel to the Gulf of Mexico. I know that much has been said in regard to my position on this question. I believe in it as a matter of policy, not as a matter of immediate achievement, and that whatever is done in Chicago should be done in harmony with that policy. As an engineering problem, I have not the slightest question but that it is within the limits of the possible. Whether we shall ever see it or not, and when, is a question which I cannot discuss now, further than to say, that we should not attempt to stultify the future in anything we may now do.

Now, the pith which I want to get at in connection with this question is right here : What shape is Chicago in to realize any of the advantages which are to come from this twenty feet of water around the great lakes, and in what shape to benefit from any deeper channel to the sea. We have here to-day sixteen or fifteen feet of water through our Chicago River, termed for euphemy a harbor. A river here such that it has taken six hours for vessels to go six miles—plowing through the mud nearly all the way when heavily loaded—and we pay here nearly half a million dollars a year in towing bills alone. Certainly, this is a very inadequate harbor, and the marine traffic of Chicago is suffering as compared to other points. We have here, as I have said to you before, an enormous marine commerce, in itself two-thirds that of Liverpool. We have here about thirty-six miles of dock line in actual use, and an area of water enclosed by docks nearly double that of the Liverpool and Birkenhead docks. We are building a channel behind Chicago, about thirty miles long, which has, as now projected, twenty feet of water in it, which is 160 feet wide in the rock and 210 feet wide on the bottom, and 290 feet surface width in the clay, and that is quite a respectable river compared with the Chicago river, and

it runs through the city and the country back of Chicago for twenty-five miles. It could, with a small expenditure compared to its utility, be made a magnificent harbor for these vessels of twenty feet. It requires a proper channel connecting with Lake Michigan, about the location and character of which we are all significantly non-committal until our chief engineer has recommended something, and then we may all disagree with him.

That channel can be made twenty-six feet deep for about a million dollars more, which perhaps, is not a very large proportion for six feet additional water, when you consider a total of twenty-two to twenty-five million dollars that has to be expended on the work. The channel could be made of still larger proportions, or of a capacity of 1,000,000 cu. ft. per minute, for an additional investment of about six million dollars; in other words, you may add 67 per cent. to its capacity for an additional cost of 25 per cent. That would give us a channel twenty-six feet and 180 feet wide in the rock, 270 feet at bottom and 370 feet at surface in the clay. As a ship canal it would be the largest and best ship canal that was ever built. As a harbor, widened and docked in the clay, it would be something that no lake city ever before enjoyed. I mention these things as possibilities, as matters that should guide our policy so that they will be probabilities, and it is to be hoped also, early achievements.

As a member of the Drainage Board, my record is pretty strong on the question of policy, but in the matter of practical achievement, we have to content ourselves with what lies within the limits of our resources. That dictates a very plain and simple course of procedure. We can pre-empt the entire situation, for the present and the future, by securing a proper right of way, upon which all things may follow, and that cannot be taken away from us; this does not add greatly to our expenditure. We can build all the channel and the biggest channel that we have the money to pay for, and the money put into that channel is more profitably invested for the future of Chicago than in any other way. We cannot afford to invest our resources in any other way, must sacrifice dockage, water-power and other utilities until the two great objects—right of way and channel—are provided.

Five years from now the necessity for the harbor will be upon us. The question is, then, what are we going to do about it? We have got to climb the tree some way or other. If this channel is behind Chicago at that time some way will then be found to get into and to utilize it, if not found before. If Chicago has then a channel of twenty feet, or any other depth of greater amount, she will be in shape, as she is not now, to enter into any scheme for deep water to the Atlantic and deep water to the Gulf. I say it with some degree of shame, that when I went with our Chicago delegation, as a representative from the

State, down to the deep water convention at Detroit, we agreed among ourselves that we would not do any shouting on this deep water question; that there might be some newspapers in Chicago that would discover that the harbor had scant sixteen feet of water, and that Chicago men at Detroit were making noise enough to set the bells ringing, asking for twenty feet of water, and to the prejudice of the interests of the city and State they represented. Chicago has not been in position, she is not in position to-day, to utilize deep water, and it is the duty of Chicago to provide for this, or else throw up the sponge on the transportation question.

Of the total movement of Chicago, about one-third is by water, and I believe, if you can make any relative estimate of the benefit to Chicago, the water brings more wealth than the rail. That which goes and comes by water lies at the basis of your industry, and means population. A million of commerce by rail means goods and trade and a few clerks, millions of commerce by water means a city.

OUR PAVEMENTS.

By John Donnelly, Member Engineers' Club of Kansas City.

[Read January 8, 1893.]

The most important problems to the city dweller involving health and comfort are those of sewerage and pavements. Great cities with poorly paved highways are a menace to the health of its inhabitants, an added cost to all traffic and a constant source of filth and discomfort; the appearance of their streets is evidence of their style. I believe the progress and advancement of cities is better evidenced by their pavements than other municipal improvements; first efforts being generally in the direction of providing highways that are fit for travel in all seasons by improving county roads, usually by filling the soft and spongy places with stone quarried in the vicinity or gravel from the beds or channels of neighboring streams. The location of this city furnished plenty of limestone of varying hardness and quality at elevations from the river level to 250 feet above it, and under most conditions we would use our local material in preference.

The first pavement of Kansas City done by contract in accordance with ordinance passed, was begun January 8th 1857, thirty-five years ago, on the levee or steamboat landing (now Front Street) from about Walnut to Wyandotte Streets. It consisted of Telford macadam for the level or roadway part of the levee, and roughly squared blocks for the wharf or that part which sloped to the river's edge. Prices were, for macadamizing \$1.65, and for stone blocks \$1.60 per perch. The

contract does not say whether linear, square or cubic perches. I presume from the prices that square perches 16.5′ × 1′ were meant. This work was paid for by a loan obtained on the security of the Wharf Fund, a tax levied upon all steamboats stopping at Kansas City, of which the number averaged about ten daily at that time. No evidence of that pavement exists today nor has it been renewed, except eight years later in laying a track along the levee, the Missouri Pacific Railroad Company rebuilt the wharf or sloping part upon the block from Main Street to a short distance west of Delaware Street from the line of their railroad to the ordinary level of water in the river.

From 1857 until 1880 no other form of street pavement was laid in Kansas City but macadam, using the rock that came cheapest and nearest to the work done, generally utilizing such as came from the cutting of new streets through the hills and bluffs of Kansas City. By January 1st 1871, Kansas City had about ten miles of such pavements and which was increased by January 1st. 1880 to fifteen miles. In 1880 Fifth Street from Broadway west to Bluff Street was paved with sandstone blocks from the vicinity of Buffalo, New York, (Medina Stone,) our first stone block pavement; and in 1882 was begun the relaying of some of our macadam streets with cedar blocks, generally upon concrete base, from which time until within the last two years the city has laid but a small amount of macadam pavement.

January 1st 1885, we had pavements aggregating 22 miles in length divided as follows:

Macadam	10.6	miles.
Cedar Blocks on Concrete	9.6	"
Cedar Blocks on Boards	0.6	"
Stone Blocks	1.2	"

In 1883 Bluff Street from the Bridge to Fifth Street was paved with stone blocks of Argentine Limestone, and in June 1886 the same street was repaved with Colorado Stone, replacing Argentine Limestone blocks worn out after less than three years of wear.

In 1887, several streets were paved with cypress blocks from southeast Missouri and northeast Arkansas, upon the same plan usually followed in laying cedar blocks.

In 1888 the first asphalt street pavement was laid and in which the contracting company agreed to maintain the same in good order for a term of five years from and after its completion and acceptance.

Toward the close of the year 1889, the first pavement of vitrified brick was laid, and during the same year Sixth Street west of Broadway was repaved with cedar blocks, the first blocks having worn out after six and one-half years of use.

On April 1st 1890, our paved streets aggregated as follows:

Argentine limestone blocks	0.20	miles.
Asphalt	4.47	"
Cedar blocks on boards	29.91	"
" " " concrete	20.94	"
Colorado sandstone blocks	1.14	"
Cypress blocks	0.77	"
Missouri Granite	0.40	"
Medina Stone	0.21	"
Macadam	4.33	"
Vitrified Brick	0.66	"
Total mileage	63.03	"

The decrease in the length of macadam streets is the result of re-paving with other material. In 1891 we returned to the use of macadam, usually finished with a top dressing of bank gravel.

At the present time, our paved streets are as follows:

Asphalt	9.66	miles.
Cedar block on concrete	21.86	"
" " " boards	29.60	"
Vitrified brick	4.02	"
Stone blocks, granite, Medina, Colorado	2.38	"
Macadam, gravel etc	4.21	"
Total	71.73	"

COST OF CONSTRUCTION.

Asphalt has cost from $2.25 to $2.80 per square yard according to thickness of wearing surface and concrete base necessary to lay the wearing surface.

The cost of macadam has varied from 55 to 95 cents per square yard; cedar blocks on concrete from $1 35 to $2.55 per square yard, and on boards from $1.10 to $1.75 per square yard.

Cypress blocks were laid at a reduction of about 10 cents per square yard below the prices then prevailing for cedar blocks.

Sandstone, granite and other stone blocks cost from $2.50 to $4.00 per square yard.

Vitrified brick usually laid upon concrete base has cost from $1.40 to $2.10 per square yard. The prices being such as the work is let for, payable in special tax bills, and does not fully show what is the cost of brick paving because such bills are slow sale, except at a large discount.

Probably a fair statement of the cost of paving, as laid at the present time in this city and payable in special tax bills, is as follows:

Asphalt, Business street	$ 2.80	sq. yd.
" Residence street	2.50	"
Vitrified brick, asphalt joints	1.85	"
" " plain	1.60	"
Cedar blocks, repaving on concrete	1.10	"
Macadam	.75	"

Macadam will last as long as you repair and take care of it. Cedar blocks on concrete will continue in fair condition for five years; and with some attention, sprinkling and repair, it may answer for service four years longer. Cedar blocks on boards will last about four to seven years, when it gets beyond repair and must be renewed. Cypress blocks, about three years the material appears to rot and become bad in a very short time after being laid. Colorado sandstone under heavy traffic, about five to ten years, at which time, if relaid using some new blocks, it will last an equal period. Granite blocks will ordinarily need relaying in fifteen years, but is the only kind that will endure under heavy city traffic.

Brick, if you get the right kind, will endure under ordinary traffic, about ten years; on narrow streets under heavy traffic, it can hardly last that long.

Of the durability of Asphalt, I am not as well prepared to speak. The city of Washington, among the first to pave with asphalt, is still using streets paved more than fifteen years ago, although portions of it have been patched and repaired, no general reconstruction of the street has been made. Our neighboring City of Omaha has pavements in fair condition after ten years of wear, and while seamed and cracked from shrinking of the wearing surface, are apparently good roadways and can yet be cleaned fairly by a street sweeper, and are as good for general travel as when first laid down.

At present, this city contracts for brick and asphalt pavements with a guarantee of maintenance in perfect condition for a term of five years after completion. This gives some security against bad brick and improperly prepared asphalt, but with the asphalt pavements the problem will be how to protect and take care of them when this guarantee has expired.

As to how we shall pave our streets or renew our pavements in the future, I cannot foretell. I am of the opinion that but a small proportion of cedar block streets will be relaid with that material. There is some demand for its use upon portions of Pennsylvania Avenue and Eighteenth Streets, but the demand comes apparently from owners who will look for the cheapest material in preference to the best. Both streets are safe and fairly passable, although the surface is rough and uneven, and their reconstruction as well as that of about ten miles of other streets paved with the same material, appears to be needed. In

my opinion, owners fronting on such streets have received fair returns for their investment in most of the pavements now going to decay, and should a majority of the resident owners desire to reconstruct with cedar blocks upon the concrete previously placed, their wishes should be consulted and agreed to. Where the pavement to be renewed is on boards, there is no advantage in reconstructing with like material. Concrete should be placed under either blocks or brick, and I think there will be but slight difference in cost and that brick is the most durable.

Generally, most of the streets will be reconstructed in vitrified brick, mainly on account of its cost and the further fact that not one dollar of its cost need be sent away from home for material, being like macadam, a home industry. A large portion of those decaying streets will be reconstructed with asphalt, the street pavement that will please the tenant or renter of business house and residence. When like Main Street, a new pavement is laid, its cost represents but a week or two's rent, even at present prices, and although a greater first cost, the street that will attract most people can afford the highest rent and the owner of the property is greatly interested in having the best pavement.

I do not advise laying asphalt pavements on streets having over four per cent. grade. I think asphalt on Main Street from Missouri Avenue to Seventh Street a mistake. It will not make a difference unless we should also repave Walnut Street and Grand Avenue, having grades about the equivalent of Main Street, five or six per cent. with like material. The effect will be to drive heavy teaming, such as coal, sand, brick, stone etc., off those streets. It may be to the advantage of Main Street that some of this traffic be excluded, for on busy days the street is too crowded, but it will not do to deprive that traffic of a route through the business center nor will a pavement of vitrified brick be less objectionable upon a six per cent. grade. In my belief, until the surface becomes worn and rough, a horse will have no better foot hold than upon asphalt.

For the utility of the street as a thoroughfare for general teaming, Walnut Street, Grand Avenue and Twelfth Street, when the grade is in excess of three and one-half per cent. should be reconstructed with granite or as good and much cheaper, porphyry or jasper from the vicinity of Sioux Falls, Dakota. I do not think so well of the wearing qualities of Colorado sandstone, as laid upon Bluff Street and Union Avenue. Both Streets are in need of reconstruction and Bluff Street is in use but little over six years.

For our heavy traffic, let us use Missouri granite or the Dakota stone. For other business or residence streets, asphalt in such cases as those who pay for it express a preference, and generally for other

streets, use vitrified brick in such portions of the city as desire their street cleaned frequently. The three classes just named ahould be cleaned daily or semi-weekly by contract, to be done as often as adjacent owners may desire and at their cost.

For the remainder of our streets, we will use macadam or a combination of macadam and gravel. They are good for driving, will wear well, unless the traffic be too heavy, and answer well if they are sprinkled and taken care of by the authorities. They should be cleaned and repaired, and, in my opinion, the great objection to macadam, gravel, streets is because they are not cleaned and repaired. When you seek a reason why it is not done, you will find it is the cost of the service. In my opinion, it will cost less to construct, maintain, repair and clean an asphalt street than a macadam or gravel street during a period of twenty years.

The cleaning of brick or asphalt can be done by machinery; the cleaning of macadam can only be done by hand labor. Therein lies the difference of cost. I suppose there will be no dispute as to which pavement is most desirable.

In conclusion, the paving question is not settled and quite likely never will be. The city of Paris removes Asphalt to put down wood; the City of London removes granite to replace it with asphalt; the City of New York covers her granite or trap (Basalt) blocks with a sheet of asphalt to deaden the noise; and Chicago and St. Louis keep on putting down granite blocks as if there was no other suitable material on earth, and the more noise you have, the better. A number of interior cities from Columbus, Ohio, to Lincoln, Nebraska, are using brick and think there is no better material to be had, and in those cities fortunate enough to have Parks and Boulevards, such highways paved with macadam and gravel are the best and safest driveways on earth. Finally we will try to pave and repave our streets with material the choice of the men who pay for it, and trust they may become educated to know what is best.

TECHNICAL EDUCATION IN MONTANA.

BY PROF. A. M. RYON,* MEMBER MONTANA SOCIETY OF CIVIL ENGINEERS.

[Read January 14, 1893.]

One of the principal objects of any Engineering Society is to give at its meetings opportunities for a free exchange of thought and experience. In this way every member has an opportunity to learn what is going on throughout the section represented by his Society, and it

* Of the College of Montana.

seems fitting that every engineer should be informed as to the progress and standing of the engineering educational institutions of his State, for the ranks of the profession will be recruited to a large extent from these institutions. Unfortunately it is impossible to show in a paper or a discussion the exact relative efficiencies of institutions of learning. While it is fair to presume that an old institution, whose graduates as a whole show a creditable record, is a safe one to patronize, yet a younger institution may be fully as good or even better. The size of the institution I regard as no criterion whatever and from what information I possess on the subject I would judge that some of the best institutions are amongst the smaller ones. In support of this view I will quote an eminent engineer in the *Engineering News* of June 9th, 1892. "Were it possible to grade our engineering schools in the order of absolute merit it may well be that some one or two of the smaller schools would stand at the head of the list * * * * * a strong argument might be made of the position that just as the books and newspapers of largest circulation are rarely the best and often the worst, so the college which attracts the largest number to its course stands condemned of certain elements of inferiority."

At the present date the different engineeering professions have branched out in to so many specialties that engineering colleges make no special provision for many of them in their regular curriculums, and the student desiring to follow up a particular branch of the, profession, such as bridge building, heating and ventilation, or hydraulic engineering, is obliged to take a post-graduate course. Comparatively few do this, however, preferring, and perhaps wisely, to study their chosen subject in the office or field. The general principles of these specialties are, however, taken up in the regular engineering courses, and during the four years course common to the majority of colleges, there is but little time for anything else after the necessary preliminary mathematical work is finished; nevertheless, in spite of the shortness of the time, all engineering institutions aim to give their students sufficient practical experience in surveying, draughting and, in the case of mining schools, assaying and analytical chemistry as well to enable them to secure positions after graduation. While some time might be gained by increasing the number of departments in the college, thus enabling students to concentrate their attention upon their chosen specialties, yet this gain would not be considerable, as a thorough preparation for any one of the special courses in engineering would amount to about what the colleges are now giving as a general course.

As the subsequent employment of the graduate depends usually upon circumstances over which he has but little control, rather than upon his own deliberate choice, the majority of students would prefer a

general course starting them in several directions and thus giving them better opportunities of getting employment, as well as information which would enable them to make an intelligent choice of a specialty in case they have such an option. For the reasons just given, and others which might be added if time permitted, the strictly engineering college of to-day finds it desirable to restrict their departments to civil engineering, mining engineering, mechanical engineering, electrical engineering, sanitary engineering and a department of metallurgy. The most prosperous of these courses today is that of mechanical engineering. The department of electrical engineering which is very closely allied to that of mechanical engineering bids fair to out-rival all the others in a few years. The attendance in mining departments is smaller than that of the other departments with the exception of the departments of metallurgy and sanitary engineering. I will not take the time to give the reasons for this state of affairs, but will say in my opinion at least the reasons which have rendered the mining course comparatively unpopular in the East do not apply in Montana.

The advisability of modifying the present mining courses, with a view to making them more popular, is now being discussed by the professors of mining in our institutions of learning. It may be appropriate here to quote a few points bearing on the engineering colleges of the United States. The first engineering college established in the United States was the Rensslaer Polytechnic. This institution was started in 1812 at Troy, N. Y. The first State engineering college was started at the University of Michigan in 1852. Since that date the number of engineering schools in the United States has increased rapidly, there now being 52. The total number of graduates from engineering schools in 1892 was 938, including all departments.* In order to convey an idea as to how our school of Mines at Deer Lodge, which is the only technical school in the State, stands in comparison with other institutions, it is interesting to note that out of the 17 mining schools in the United States we rank number 9 in point of attendance. In 1891 but six mining schools graduated more students than we did. The greatest number graduated from any one being six, that institution being the University of California; Columbia School of Mines ranked number two with five graduates. In 1892 there were still but six institutions which graduated more students. The greatest number of graduates being nine from the Michigan Mining School (a three year's course) and nine from Columbia School of Mines.

As the School of Mines at Deer Lodge is the youngest mining school in the United States being but 5½ years old, we are not ashamed of this

* Since the above was written a College of Agriculture and Mechanic Arts has been started at Bozeman, Montana. This institution will have an engineering course. A. M. R.

record. Of the 52 strictly engineering colleges, there are to the best of our knowledge and belief but two mining schools which give more hours per week to recitations, lectures, field and laboratory work, and the draughting room; these are the Union college of Georgia and the Union of Wisconsin. Of the civil engineering colleges Swarthmore and Union Colleges exceed the time allotted by the Montana School of Mines. The latter gives 35 hours per week; not including Saturdays and special work in the field. The Washington University of St. Louis is the only engineering college in the United States requiring a five years course to obtain a degree. This covers a period of 200 school weeks. The Montana School of mines together with seven others comes next, each requiring 160 weeks work during the four years course. The mining course of the Montana School of Mines occupies 256 hours more time than any other mining school in the United States, the nearest approach to it being the Union College of Ga.* In some respects our Montana School of Mines has had unusual difficulties to contend with. During the first two or three years of its existence there were but few high schools in the State. All of its students were drawn from other departments of the College, and even to-day we are obliged to depend very largely upon our preparatory department for our College students. The progress of high school work in this State during the past few years has been remarkable and reflects great credit upon those who have had charge, and we have already felt its effects in the improved material which has come to the College of Montana during the past two years. The perfection of the high school system in Montana means the removal of the greatest obstacle with which our technical education has had to contend.

The work at the Montana School of Mines during the four years course is divided so that the mornings are given to recitations and the afternoons are given to chemical analysis, mineralogy, blow-piping and assaying in the laboratory, and draughting, engineering design and surveying in the engineering department. The institution is well supplied with laboratory and field apparatus, although our laboratory quarters are rather cramped, this defect will, however, probably be remedied inside of a year, Mr. W. A. Clark, of Butte, having recently contributed $2,000.00 towards the erection of suitable quarters. We have not yet advanced to that degree of affluence which would enable us to provide our rooms with polished hard wood finish and nickle plate trimmings, but then we have all that is necessary for good under-graduate work.

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*The information upon which these statements were based has been found to be incorrect in some particulars. Later reports indicate that there are about fourteen institutrons which give as much or more time to their courses as we do. A. M. R.

In point of ability we find that our average student differs but little from those found in eastern institutions, but owing to our small classes we are able to give them more personal attention than is possible in the case of larger institutions so that the quality of the work done will compare favorably with that of any of the engineering institutions of the United States. This sounds like a rather strong story from the wild and woolly section of the country, where many in the east suppose that the schools are held but a few months of the year in log shacks and I would feel some hesitancy in making the statement if it were not for the fact that we keep samples of our work on hand for the inspection of our visitors, and before closing I would like to state that no visitors would be more welcome than the members of the Montana Society of Civil Engineers.

ON SOME PHYSICAL PROPERTIES OF STEEL AS RELATED TO ITS COMPOSITION AND STRUCTURE.

By John W. Langley, Member Civil Engineers' Club of Cleveland.*

[Read January 10, 1893.]

For the purpose of this paper it is desirable to have a definition of steel from the chemical rather than the mechanical standpoint, because it takes up the subject mainly from the molecular and internal side rather than from its engineering aud commercial one.

Steel, then, may be defined as iron holding in solution, in whole or in part, other elements within certain regulated limits. Cast iron and ferro-silicon are not included. The elements which it must contain to fulfill practical requirements are carbon and manganese. Those which it inevitably gets from the present processes of manufacture are silicon, sulphur, phosphorus, and, probably, oxygen, hydrogen and nitrogen. These are not essential elements, for their relative proportions and amounts may be varied, and indeed by special care one or two of them eliminated altogether, without depriving steel of its well-known qualities.

Besides the above there may be present, as accidental impurities, about fifteen other elements; generally, however, the quantities of these will be very small except in the case of alloy steels where they are intentionally added. The principal alloy steels are those of tungsten, chromium, manganese and silicon.

The alloy steels shade by insensible gradations into hard, brittle,

*Some portions of this paper have already appeared in the transactions of the American Society of Civil Engineers for Oct. 1892.

Many of the data and some of the opinions here offered are the result of the joint labors of Mr. William Metcalf and the writer.

bodies, incapable of lamination. Throughout this paper the word "steel" will be restricted to those metallic masses composed principally of iron, which are ductile and capable of successful working under the hammer or between rolls; also which possess initially or by sudden cooling a considerable degree of hardness greater than that of wrought iron.

The following table gives the approximate quantity of the more important elements occurring in steel:

TABLE NO. 1.

Percentages of Elements.	Commercial Steels.		Alloy Steels.	
	Upper Limit.	Lower Limit.	Upper Limit.	Lower Limit.
Carbon	1.50	.30	2.25	1.25
Silicon	.30	.02	1.50	.50
Sulphur	.10	.005	.10	.005
Phosphorus	.10	.01	.30	.01
Manganese	1.00	.08	15.00	5.00
Tungsten	—	—	7.00	.50
Chromium	—	—	2.00	.25
Oxygen	.20 ?	Traces.	—	—
Hydrogen and Nitrogen	Very little.	Very little.	—	—

In Table No. 1 the lower limit indicates those quantities of the elements at which their specific action ceases to be sufficient to give the "alloy steel" special properties.

The lower limit of carbon in commercial high steel is given at 0.30, because, below this, the metal becomes incapable of any notable amount of hardening when suddenly cooled.

The upper limit for oxygen is queried, because there are no wholly satisfactory methods of analysis for this element in the presence of large quantities of iron.

Hydrogen and nitrogen have been found in small quantities in all steels. Carbonic oxide appears likewise to be a universal ingredient of steel.

Since steel has been defined above as a solution of certain elements in iron, it may be proper to state here the meaning attached to the word "solution."

Chemical action appears to take place in at least two very different degrees of intensity. When it is exhibited in its maximum power and unopposed by other forces, it results in the production of chemical compounds, having, as every one knows, definite and fixed proportions of each ingredient. These are customarily spoken of as atomic combinations, it being assumed that they are formed by the juxtaposition of elementary atoms by a process of addition in which, necessarily, a

whole atom is taken on each time. Experience shows that the number of such unions between any one pair of elements is quite small, generally one or two, and never exceeding seven.

To express this idea of definiteness of composition mathematically, consider the case of two elements, A and B, taken in the proportions by weight of x and y respectively. Then, in general, the compound, $Ax + By$, cannot be formed for arbitrary values of x and y for, as soon as x parts of A are taken, it will be found that the value of y depends on Ax and B, so that $y = x\frac{A}{B}$ and the numerical value of $\frac{A}{B}$ depends on the elements chosen. In the case of hydrogen and oxygen, it has the value of one-sixteenth.

Moreover, if in the compound $A + B$ we make A constant, then we cannot vary the quantity of B by infinitesimal increments or decrements, for B also will remain constant until some simple multiple of itself is reached which will permit of the proportion $A + 2B$ or $2A + B$ being formed.

In chemical compounds of the above type, there is always a profound alteration of the properties of A and B considered individually.

Now, in the case of solution, the actions appear to be very different. When salt or sugar is added to water a kind of combination, certainly, takes place, for both of the solids disappear and will continue to do so till the point of saturation is reached; but this is not a fixed point, for it varies enormously for most bodies with the temperature, and is also slightly changed by pressure. The phenomenon is characterized by a gradual modification of the properties of the solvent. Thus, the water grows progressively sweeter, or more saline. If gum is added to it, it becomes more and more viscid; hence, indefiniteness seems to be an attribute of the act of solution. To adopt the former notation, the compound (solution) $Ax + By$ can be formed for wide variations in the values of x and y. If one of the bodies is fixed in amount, then the other can be changed by infinitesimal increments and there will be a corresponding alteration in the solution as a whole. Finally, the change in the individual properties of the ingredients is gradual and usually not very profound. The nearer the reaction in dissolving a substance approaches the first or combinational type, the more complete will be the change of properties.

A complete theory of solution has yet to be formulated. Chemists and physicists are not agreed as to the kind and extent of the chemical actions which may take place, but all are agreed that the obvious visible phenomena of solution are different from those of typical chemical combination.

Now, looking at the behavior of steel, whether melted or solid, I am forced to regard it as exhibiting mainly the characteristics of solution,

for fusibility and the property of hardening increase directly with the quantity of carbon added to it up to a certain limit, while its ductility decreases with the carbon. The analogies are very close in another respect; when crystallization from solution takes place, there is a strong tendency for the crystals to partially purify themselves by extruding foreign matter not necessary to their formation. Similarly, when steel solidifies, it always ceases to be perfectly homogeneous, the last portions to set containing an excess of some of the dissolved elements, notably carbon and phosphorus. This, which is called "segregation," is a very troublesome phenomenon and one which forbids us to hope ever to make, by the present appliances, the highest grades of tool steel in large masses.

Steel, then, is a solution of certain bodies in iron, and this definition applies to it, not only while it is melted, but also when solid, for changes in the distribution of the elements within a mass of steel can be produced while the metal is yet far from the liquid state.

In 1861 St. Claire Deville discovered the fact of dissociation, a process the opposite of chemical combination, whereby compounds may be resolved into their constituent elements.

Since then several independent lines of reasoning—thermal, electrical and chemical—point to the conclusion that all componds when in solution tend to dissociate. I proved experimentally ("Proceedings American Association for the Advancement of Science," 1883,) that even such stable bodies as the sulphates and chlorides of the alkalies and alkaline earths showed evidence of decomposition when dissolved in a large volume of water. By analogy, therefore, it would seem that if definite carbides, oxides and phosphides were introduced into melted iron, they would tend to, and to a certain degree actually would, become dissociated and exist as dissolved bodies distributed throughout the iron, which would be modified by their presence.

Influence of Certain Elements.

The action of all foreign matters on iron when melted with it is governed by the following general law:

"Each addition to iron of small quantities of the five elements commonly occurring in steel, viz., Carbon, Silicon, Phosphorus, Manganese and Sulphur reduces the melting point, the ductility, and the electric conductivity of the iron, while at the same time it increases the hardness and the magnetic retentivity."

Taking up the influence on certain mechanical properties of steel exerted by each of the first four elements named it will be convenient to exhibit them in the form of curves drawn on a diagram having rectangular axes, where y represents the mechanical property under consideration and x the quantity of the element added. It will be found in all cases that the curve will not be a straight line, that is, the property

is not a linear function of the amount of the element. Generally speaking the curves will approximate to the equation $y^2 = p\,x$ but not accurately so, for p appears to be slightly variable.

The most notable effect of silicon is to lower the melting point of iron. When carbon is also present it somewhat reduces the hardening effect due to the latter. In cast iron this effect is a prominent one. The joint effect of silicon and carbon is to lower the melting point and to nearly abolish the plastic stage of incipient fusion on which the property of welding depends.

The following curve Fig. 1 illustrates this.

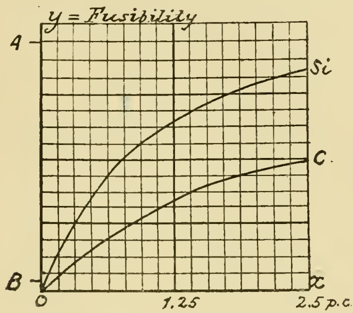


FIG. 1.

A = Melting point of Cast Iron.
B = Melting point of Pure Iron.

One of the most important properties of steel is that of becoming very hard when heated and plunged into water. Carbon is the principal element which does this. Manganese also will harden iron and in quantities of from 10 to 20 per cent., it will make a steel nearly file hard, only this hardness is permanent and cannot be removed by annealing.

The effect of these two elements is shown by Fig. 2 where the full carbon curve stops at 1.50 per cent., because beyond that quantity the steel becomes too brittle.

The best steel is that which is both hard and tough. Mere hardness is easily attained, but then brittleness also comes in.

To ensure sufficient toughness so that a tool may hold an edge when working on hard material all the elements except carbon must be kept very low in amount. Fig. 3 is intended to show the influence of these elements on a steel containing 1.25 per cent., of carbon.

A is a high grade of tool steel.

B is common Bessemer.

The disposition of steel to crack during hardening in water is often very troublesome. It is promoted by excessively high carbon and is

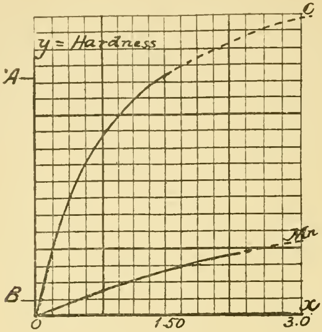


FIG. 2.
A = High Steel.
B = Pure Iron.

particularly fostered by manganese which, therefore, must be kept as low as possible.

In Fig. 4 the carbon line starts at 1.25 per cent., because steel rare-

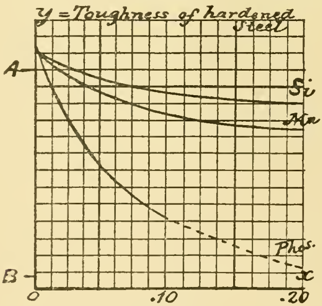


FIG. 3.

	A	B
Si	.12	.10
S	.004	.04
C	1.25	1.25
Mn	.15	.80
Phos	.01	.11

ly contains more than this. Manganese is shown to be more powerful than carbon above the 1.25 per cent. limit in causing cracking.

Some Physical Properties of Steel.

The most remarkable physical property of high steel, the one which gives it value as distinguished from iron and other structural metals, and the one which belongs to it almost exclusively, is that of becoming intensely hard when cooled rapidly from a temperature a little above redness. This subject has long exercised the minds of metallurgists, physicists and chemists.

If a bar of high steel is broken by a transverse stress, the fracture will be rough and crystalline; this appearance is spoken of as the *grain* by practical steel-makers. It refers primarily to the broken surface and it does not assume that the internal arrangement in the undisturbed particles of the bar at a distance from the end will be identical with the appearance of the fractured surface, because, at the moment of rupture, the metal is subject to compressive and tensile strains which

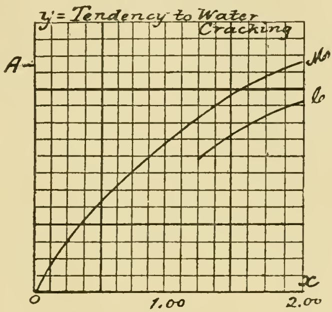


FIG. 4.

A = State at which a 4 in. round bar will crack in normal hardening.

must have an important effect in placing the particles in the final state where they become visible on the surface. But while there is not identity of arrangement, still there will be a constant relation between the superficial and internal particles, so that it is legitimate to classify steel by its fracture. The term grain, then relates to the crystalline structure of the metal, and it must be carefully remembered that it does not imply either a fibrous or a cellular structure. In fact, steel which has been thoroughly melted is wholly free from fiber or cells. William Metcalf devised, in 1876, a simple but beautiful method of showing the dependence of the grain upon the temperature at which a piece of hot steel is cooled in water. His method is the following: Take a bar of steel about three-fourths of an inch in diameter and nick it with a chisel in six points about an

inch and a half apart, and number them. Now, heat the bar so that the No. 1 piece at the end shall be nearly white hot and scintillating, while No. 6 is not red hot, the temperature varying gradually between these extremes, and having approximately the following optical appearances: No. 1, scintillating; No. 2, yellowish white; No. 3, lemon yellow; No. 4, orange; No. 5, reddish orange; No. 6, black. Now, cool the bar in water and break it into six sections. Then the fractures will appear as follows:- No. 1, coarse brilliant sandlike particles, very hard, but which crumble off readily. Probably the piece will be cracked down its side. No. 2, brilliant and sandy, but the grains smaller than No. 1; probably it will be cracked. No. 3, a brilliant gray crystalline background, showing sandy particles. No. 4, a very fine grained satinlike luster, the individual grains about $^1/_{6000}$th of an inch apart and wholly free from a sandy appearance. This is called the refining point. No. 5, like the preceding, but coarser and with a softened luster. No. 6, more decidedly crystalline, the grain coarser than No. 5, and the luster softened as though an infinitesimal film of oil was on the surface.

On trying the above with a file, No. 1 will be found glass-hard, but destitute of strength; No. 2, glass-hard and a trifle stronger; No. 3, very hard and moderately strong; No. 4 will scratch glass with difficulty, but is very strong and elastic; No. 5 can be filed, is very elastic; No. 6 soft. No. 4 gives the maximum of useful properties; it is that at which hardness and ductility are combined in the best proportions. This refining point is then a critical temperature condition, at which all steel should be hardened. It is not rigidly fixed, however, for it varies with the quantity of carbon in the steel. The above description applies to steel holding about 1 per cent., of carbon. The refining point will move up the temperature scale, *i. e.*, towards the hotter end, the lower the metal is in carbon.

The appearances noted above are intimately connected with the change of shape in the crystallization, *i. e.*, grain of the steel, and also with powerful internal stresses which are probably molecular in character; also with chemical differences in the amount of dissolved carbon. The evidence for this statement is ample. The changes in grain are directly visible to the eye, also they can be noted mechanically by the concomitant variations in hardness and ductility. As to the existence of internal stresses, the cracking of overheated pieces and the retraction of the edges of a ring of hardened steel after it has been broken show the fact clearly; also there is a change of volume on hardening. This is an expansion, the amount of which varies with the quantity of carbon in the steel and the degree to which it was heated at the moment of plunging it into the water; it is sufficient in amount to decrease the specific gravity to a notable degree. In 1876, I made some tests of Crescent steel, the results of which were published in the "Proceedings

of the American Association for the Advancement of science," of that year. The following table summarizes them. The first vertical column gives the numbers of a set of ingots differing from each other in carbon, but alike in other respects. The upper horizontal line gives the numbers of the nicked pieces broken off from rolled bars made from certain ones of these ingots, and heated at one end as has just been described. No. 5 was black hot, and No. 1 scintillating. In the columns below these numbers are the corresponding specific gravities:

TABLE NO. 2.
SPECIFIC GRAVITY TABLE.

	Specific Gravity. Ingots.	Carbon.	Bar. Rolled.	No. 5.	No, 4.	No. 3.	No. 2.	No. 1.
1	7.855	.302	—	—	—	—	—	—
2	7.836	.490	—	—	—	—	—	—
3	7.841	.529	7.844	7.831	7.826	7.823	7.814	7.718
4	7.829	.649	7.824	7.806	7.849	7.830	7.811	7.791
5	7.838	.801	—	—	—	—	—	—
6	7.824	.841	7.829	7.812	7.808	7.780	7.784	7.789
7	7.819	.867	—	—	—	—	—	—
8	7.818	.871	7.825	7.790	7.773	7.758	7.755	7.752
9	7.813	.955	—	—	—	—	—	—
10	7.807	1.005	7.826	7.812	7.789	7.755	7.749	7.744
11	7.803	1.058	—	—	—	—	—	—
12	7.805	1.079	7.825	7.811	7.798	7.769	7.741	7.690

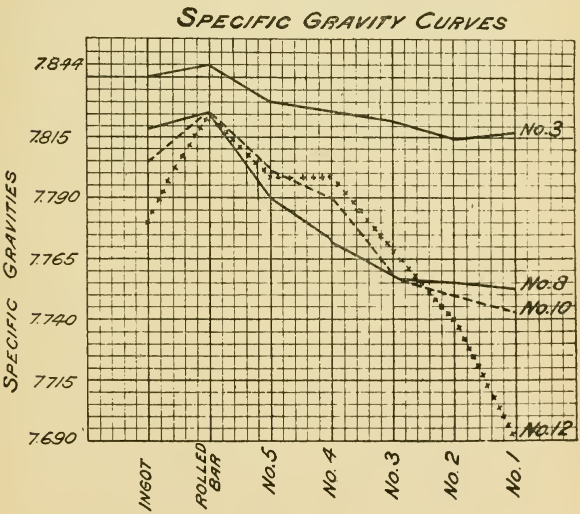


FIG. 5.

While the decrease in specific gravity varies with the increase in temperature in a general way, some of the horizontal lines show a few numbers differing from this, which is doubtless owing to the practical impossibility of heating all the pieces to exactly the same temperature.

In Fig. 5 the specific gravities for ingot and bars numbered 3, 8, 10, 12, have been plotted as curves. It is interesting to note that the effect of rolling has been to increase the density. Also that the decrease in specific gravity increases with the quantity of carbon, as shown by the way No. 12 pitches down to the base line while No. 3 is approximately horizontal. The refining point is that of the temperature corresponding to the figures in the column headed No. 4 at the bottom.

William Metcalf has found the explanation of the liability of steel to crack in hardening in the expansion which it undergoes, as the above table of specific gravities proves.

The violent stresses set up by differences in the amounts of the expansion of hardening of parts of a bar due to overheating, or to unequal heating, account, in his judgment, for cracking, and lead to the practical injunction not to heat the steel any higher than the minimum necessary to harden it, *i. e.*, the refining point. In Fig. 3 the ordinate at 5 shows the state of the metal heated to an incipient red. This is enough to remove the increased density of the rolled bar and probably all internal strains. It shows the state of the steel at what may be called normal density. Now, the ordinate at 4 shows the refined and hardened metal, consequently the stresses due to hardening will be proportional to the differences between these two ordinates, which are slight; but if the steel has been heated to the temperatures corresponding to ordinates 3, 2 or 1, the departure from 5 is much greater, and hence a liability to rupture. It is very rarely that steel cracks at the refining point.

The degree of hardness also varies with the quantity of carbon and the temperature of cooling. The maximum rate of change from soft to hard occurs near or at the refining temperature, but it is not strictly confined to this point. If a bar is nicked and heated, as previously described, and then tested with a file, beginning at the cold end, a very slight increase in hardness can be felt till we come very near the refining point, when a very great increase occurs, and the file ceases to bite and slips over the surface. For all higher temperatures it will continue to slip, so that the bar seems equally hard up to the end which scintillated. But this is owing to the file being no harder than the test piece. If a diamond is used it will be apparent that there is an increase of hardness above the refining point. From tests recently made the following curve has been constructed.

In Fig. 6 the curve starts from the annealed bar. At *A* it begins to

enter upon the refining stage. The curve now becomes nearly parallel to the axis of hardness. It is not possible to give quantitative precision to the axis of hardening, because there are no trustworthy means for measuring this properly. The sensation to the hand when moving a diamond over the pieces of steel, together with a microscopic examination of the scratch, leaves no doubt that the metal cooled from temperatures above the refining point sensibly gains in hardness, although the increase is not large. The chief gain in hardness is at, or near, the refining point. An angular fragment from piece No. 1 will scratch No. 4 more readily than it will scratch itself.

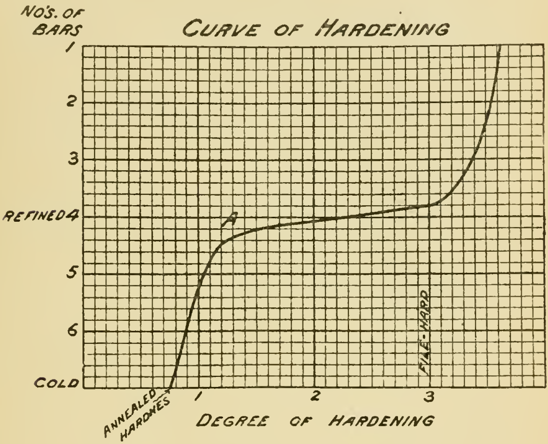


FIG. 6.

RECALESCENCE.

It has been known for some time that if a steel wire is heated to a yellow-orange temperature and allowed to cool, its light will fade away till it is nearly black hot, *i. e.*, barely visible in a darkened room, when it will suddenly begin to glow afresh, and then fade away the second time. This phenomenon has been called recalescence. Recently, it has been examined by Osmond, of Paris, and Roberts Austen, of London, each observer using very delicate electrical pyrometers by which accurate registration of temperatures was accomplished. These observers show that recalescence is not confined to wires, but takes place in a mass of steel however large, only it is not readily exhibited to the eye, except in quite small wires.

They show that if the pyrometer is inserted in a piece of steel

which is cooling down from a high temperature, and the results laid off as in Fig. 7 there will be an abrupt arrest of the descending pointer at one spot, marked *A* in the figure, as though the cooling had been stopped. This is the point of recalescence, which is at 655 degrees Centigrade according to Roberts Austen. What has really happened is this: the cooling goes on continuously, but at this point the sudden generation of heat from within balances the external losses, and so the pointer has only the horizontal component of its motion left.

Osmond has shown that a similar point exists for pure iron at 855 degrees C., only it is not so strongly marked. He thinks that this denotes a molecular change in the iron, while the 655 degrees point in steel indicates a change in the relation of carbon to iron. Roberts Austen has also pointed out that the temperature at which steel ceases to

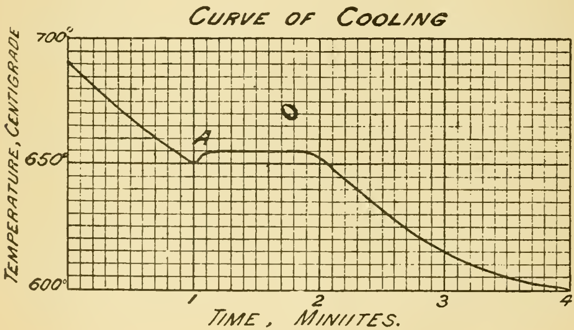


FIG. 7.

be magnetic is identical with the point of recalescence. He also says it is impossible to harden a piece of steel by plunging it into water at any temperature below the recalescence point.

Very recently, in connection with William Metcalf, some experiments were carried out which throw additional light on the phenomena of hardening. We heated by electricity wires varying in diameter from .035 to .250 of an inch, composed of steel holding 1.30 per cent., of carbon and very little of any other element. When using the smaller sizes the wires would cool down to nearly black before recalescence set in, the temperature then rising suddenly to an orange color and then fading slowly away. Moreover, if a cold wire was slowly heated up, there was a prolonged arrest at a dark orange color, after which a sudden apparent access of heat would set in and the wire would go rapidly on to higher temperatures. These phenomena make it possible to determine the point of recalescence very sharply by the eye alone,

provided it has some training in the estimation of temperatures

We found that the refining point, which, as has been already stated, is the best temperature for hardening, was identical with the point of recalescence. This is a most interesting observation, for it shows that

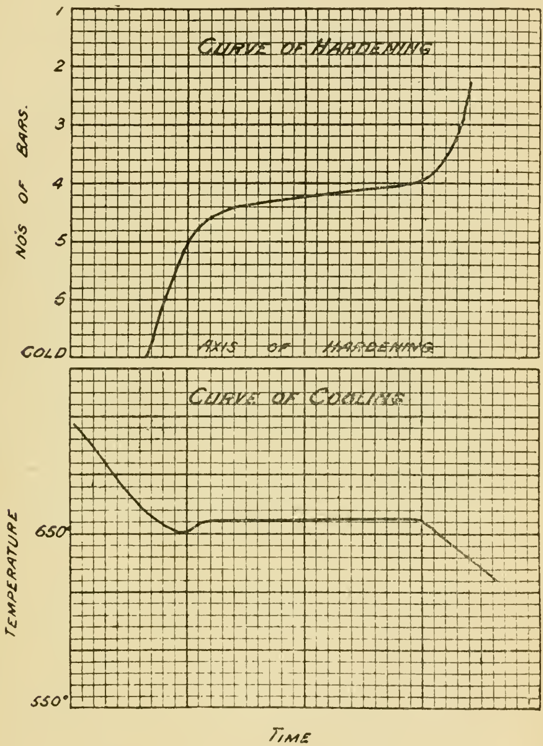


FIG. 8.

the refined grain, originally selected by the eye alone as guided by shop practice, is now proved to be that very remarkable stage in the heating of steel, where occur, in addition to the most useful degree of hardening, the loss of magnetic property and an important thermal change revealed by the pyrometer. The relation between the hardening and

recalescence temperatures may be shown by combining Figs. 4 and 5, drawing them to the same temperature scale and placing one below the other.

In extending this work I encountered a new fact. If the wire is heated to a lemon color and then allowed to cool to nearly a black and then plunged into water just before the recalescence rise takes place, it will be thoroughly hardened; but if it is heated from an initially cold stage to this same temperature, it will not harden. So this experiment proves that steel may be thoroughly hardened at much below the recalescence point.

At first sight it seems as though this contravened what has previously been said; but it does not, if the following explanation is accepted.

During the heating of the wire just below 655 degrees, a breaking

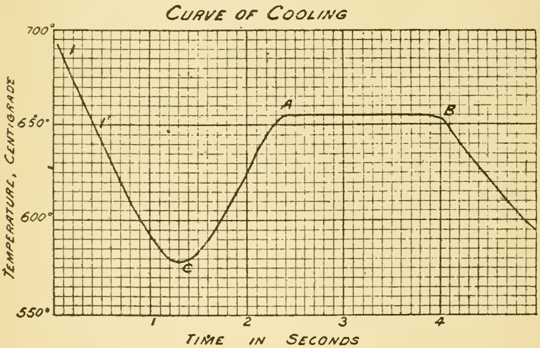


FIG. 9.

up of the crystals and a rearrangement of the particles takes place. Heat is rendered latent and is stored up, precisely as in the the melting of ice. During the cooling of the wire from a high temperature, heat radiates away uniformly till the recalescence point is reached, when the stock of latent heat suddenly becomes available at or below 655 degrees, and a brightening of the color results. A small wire can part with its heat so rapidly that it can fall considerably below 655 degrees before the particles have had opportunity to move into their permanent or cold position. Hence, the potential heat is still in them, and hardening occurs to the same degree as though the sensible temperature was higher, because of the time lag. The capability of hardening is thus shown to be a function of molecular arrangement, not of heat. Hardening seems to be dependent on temperature, only because the

latter is the best means of bringing about the favorable molecular condition.

The foreoging curve, Fig. 9 shows the behavior of a small wire when cooling. The temperatures were estimated by the eye, taking Roberts Austen's recalescence point as 655 degrees.

I, temperature at which cooling begins. *C*, lowest heat attained by the wire and point at which recalescence begins. *A* and *B*, recalescence fully established and ended respectively. For this small wire, hardening can occur by sudden cooling anywhere from *I* to *B* on a cooling curve. A large piece of steel would not harden below 655 degrees, because that part of the curve *I′ C A* could not exist for it.

DISCUSSION.

THE PRESIDENT:—Dr. Langley has given us a very interesting paper upon a very interesting subject, and one which has attracted a great deal of study all over the world among metallurgists and engineers. The subject is now open for discussion. We would like to have any one and every one take part in it, who wishes any further information in regard to the manufacture or behaviour of this wonderful metal.

MR. RITCHIE:—Mr. President, I see Dr. Langley referred to phosphorus as one of the bad elements in tool steel. Is the Basic steel the best for tool steel? That has the least phosphorus, hasn't it?

DR. LANGLEY:—Yes, and no. It has not less phosphorus than the very best brands of Swedish iron, or the best American brands of iron, such as are very carefully manufactured by the old processes. It has less phosphorus than any of the cheaper grades of structural steel. It is not the best tool steel. We know that all steel which has been melted tends to take up gases, and the complete elimination of these gases, after they have been dissolved, is impossible. Exactly what these gases are I do not know. We know that all steel contains nitrogen, and all contains hydrogen and a small quantity of oxygen. It may analyze as well as the best steel; basic stock does not make the best tools.

MR. RITCHIE:—It is considered good for structural purposes?

DR. LANGLEY:—Yes.

MR. HERMANN:—Mr. President, I would like to ask a question which is probably somewhat foreign to the subject under discussion. It relates to burnt steel: what is "burnt steel," and what is the cause of it?

DR. LANGLEY:—There have been a great many theories on the subject. For a long time it was thought that burning of steel was due to the reception of oxygen from the air, and that it contained oxide of iron. But chemical analysis has failed to show oxide of iron. It has been shown

that it can be burnt in a vacuum, as well as in a fire where air is present. "Burning" is throwing carbon out of solution by too long or too high heat, when it is nearly impossible to get it back again. If a piece of burnt steel is heated to the recalescent temperature where the yellow begins to invade the red, and it is thoroughly worked by the hammer, it can be brought back again into the active state; but you can never again get it all quite as good as if it had not been burned. Working at the yellow-red heat is the only remedy for burning.

Mr. Warner:—Some kinds require very little heat in order to harden, and others must have more. I would ask whether the proper temperature for annealing is at the point where it loses its magnetism.

Dr. Langley:—Yes, that is the point to which it should be raised.

Mr. Hermann:—That is, for annealing?

Dr. Langley:—For annealing or hardening.

Mr. Hermann:—Would it be advisable for tool-makers to have a magnet handy, and try the steel on the magnet?

Dr. Langley:—Yes, I think it should be heated till the magnet just ceases to attract it. You could hardly do that on large masses of steel; but in delicate, fine pieces it would pay to try it by the magnet.

A Visitor:—We have very large thin dies. The matter of hardening is one of great importance for the dies are extremely expensive. Is the heat uniform enough, and will that test be accurate enough for us to apply it to the hardening of dies two feet in diameter and one inch thick?

It is very difficult to get them the proper temperature.

Dr. Langley—I doubt whether the test on such a large piece would be accurate enough because a very slight difference in the diameter has a very potent effect upon it. I do not think you can test the whole surface with precision. But on a small mass I think you can. The only way to be safe is to heat them a little above the minimum temperature and let them cool to the right point.

Mr. Barber:—It is said that if chilled iron is drawn off in castings, chilled iron will remain in an undissolved condition, and that it forms into globules and is found when the article is put upon the lathe. Is this, or is it not, the case?

Dr. Langley:—I never had any such experience; never had very much personal experience with foundry work. But the segregation and formation of hard points, is a very common experience. The explanation may be found in this; iron, in order to chill well, must contain only a small amount of silicon, and if some of this iron in the total mixture is charged and then comes down without proper time for mixing it is quite conceivable that the portion which contains a minimum amount of silicon will be harder.

Mr. Barber:—In other words, you think chilled iron has not been melted?

Dr. Langley:—Yes.

Mr. Hermann:—Old stove castings which have been repeatedly exposed to high temperatures give trouble by failing to melt.

Dr. Langley:—Most of the carbon has been burned out of them, and when you heat them they behave like iron.

Mr. Hermann:—They behave more like wrought iron.

Dr. Langley:—Yes.

Mr. Hermann:—If the centers for lathes, are heated to the ordinary hardening temperature and allowed to cool down to such a red heat that it can just be seen in a dark corner, then, by plunging them into water, you can soften the same very much. I would like to know whether Dr. Langley has observed this phenomenon.

Dr. Langley:—Yes, you can get it still softer if you put it in ashes. If you take a considerable size you can get it soft if you can just see it. You cannot change the solubility of the carbon: all the latent heat has gone out of it, if it is much below the recalescence temperature.

Many members of the club have probably used self-hardening tools. It is the general impression that a self-hardening tool is harder than any other tool. This is a mistake. Self-hardening is due to one element, and that is Tungsten. The function of Tungsten is to delay the rate of change of the carbon; the phenomenon of recalescence is lost in self-hardening steel because the change is so slow. If the Tungsten metal is submitted to annealing you can both harden and anneal it nearly as well as you can harden and anneal carbon steel by simply changing the "t" in this equation (illustrating on the chart.) If you do not do that with the Tungsten steel it will crack. Many are under the impression that you cannot soften self-hardening tools. You anneal Tungsten steel about three times as long you would common steel, and you get a very nice substance. If you want to put your tools to very heavy duty and they are of pure carbon steel they will soften and stop cutting, because the heat will draw the temper. Tungsten acts simply to delay the rate of change, and you can get a tool nearly to red heat if it has Tungsten in it, and it will do its work for a long time before the change takes place. Glue water will dissolve just as much salt as pure water, but it does it more slowly. Tungsten acts to iron much as glue acts to water: it is simply a delay of the change: it does not make it any harder than carbon; it does not make it quite as hard. All practical men know that self-hardening tools are good only where you want to do heavy duty.

Mr. Hermann:—Tungsten steel is not the Mushet steel?

Dr. Langley:—Yes.

Mr. Hermann:—I read somewhere that Mushet steel didn't show

any chemical difference from other steel, and that its peculiar quality was due to some secret treatment that the steel received at the factory.

Dr. Langley:—Speaking generally that might be true in some particular specimens of the brand. But the particular characteristic of all the Mushet steel in the market is: it contains from 3 to 5½ per cent. of Tungsten.

The President:—I would ask Dr. Langley if annealing structural steel, and keeping it at a high temperature, for some time, has the same injurious effect that it has on finer grades of tool steel—if you keep it on high temperature before you allow it to cool.

Dr. Langley:—I have only had a moderate experience with structural steel. I don't think you have to be nearly as careful with it as you do with high carbon steel: it will stand more abuse than high carbon steel. There is so little carbon in it, it will stand very much abuse. Get tool steel down to $^7/_{10}$-1 per cent. carbon, and you do not have to take much care of it in the annealing; it is only in the 1-1.25 that you have to take care of it in the annealing.

The President:—Would there be any advantage in keeping it hot?

Dr. Langley:—I don't think it would, any more than to release the strains in it.

Mr. Hermann:—Some pieces of low carbon steel that were overheated and afterwards annealed, behaved more like cast iron. One of them was ruptured at a tensile strain of 91,000 pounds and the other at 99,000 pounds. They ought to have stood 120,000 pounds. The annealing did not correct the overheating.

Dr. Langley:—That was one of the characteristics of over-annealing. My personal experience has not extended into that subject with structural steel.

Mr. Hermann:—I happened to be present when one of the pieces was overheated. I didn't think it would have such an effect; but in submitting the sample afterwards to tensile strain I found that result.

Dr. Langley:—I think it would, if it was heated up to 855° C., that is where the yellow begins to pass into white.

Mr. Barber:—I believe that molten iron is the only substance in which carbon is soluble. I would ask: to what extent is it soluble? How much carbon will molten iron absorb? And at what temperature does this take place.

Dr. Langley:—Molten iron is not the only substance that will do it. Manganese will hold more than iron. The maximum carbon that iron can hold is 5 per cent. Manganese holds 6-7 per cent. and Chrome 8-10 per cent. This is at the melting point.

Mr. Warner:—I met, not long ago, a manufacturer of galvanized iron; he makes a high grade, and he also makes galvanized steel. I

asked him the difference. He said it was all the same. In these days when we have iron and steel so near the common basis I wish Prof. Langley would tell us when the steel ends and the iron begins.

Dr. Langley:—That is a conundrum that no man can answer.

Mr. Warner:—Our former President, Mr. Service, mentioned an interesting fact in this connection. He said he had seen the best iron treated chemically so it was all dissolved, leaving nothing but slag. It leads me to think that iron contains impurities which steel does not, and these impurities were necessary from its manufacture. That could all be dissolved, leaving simply slag, so that iron is really impure de-carbonized steel. If we thoroughly de-carbonize steel does it leave iron in its pure state?

Dr. Langley:—The old distinction between iron and steel is: steel is something that will harden if plunged into water. But with Huntsman's discovery of melting blister steel, and with the inventions of Bessemer, we are enabled to melt tons upon tons of cast steel. In regard to the question: where does the line of cast-steel stop, if anywhere —a committee was appointed some years ago to decide what constituted steel. There was one rate of duty on steel and another on iron. There was an international committee appointed also. I think it was decided that any form of iron which had been completely melted and changed into a fluid state and cast into moulds should be called steel, but if it had been made by means of the puddling process it should be called iron. So we can have steel containing less impurity than iron, and yet it would be steel. We can have steel that contains almost no carbon at all, or at least, only a minimum. The other question, as to whether iron is necessarily purer than steel, or not—iron is usually not so pure as steel, because a great deal of slag is retained mechanically. The molecules have been incased in the slag and they are pulled out into cylinders, and it gives iron its fibre. It is mechanically better able to stand a shock. If it is all well worked, iron will stand more abuse than steel on account of mechanical dis-continuity.

Mr. Hermann:—The presence of slag produces, what we call, fibre, and that is not an element of strength, but tends to weakness in proportion to the amount of slag or cinders.

Dr. Langley:—It is an element of weakness in one sense, and not in another. The films of cinder prevent a crack from spreading. A mass of homogeneous steel is something like a mass of glass.

Mr. Hermann:—This is in close contact with the theory of iron crystallizing under constant use. I had a conversation with Prof. Thurston, and he used the expression about iron "crystallizing;" he thought it would crystallize. I was very much surprised to hear this expression from him, but he corrected himself afterwards. There is a de-

struction of fibre which will produce crystalline surface; but I didn't know that cold iron would crystallize.

DR. LANGLEY:—That matter is not yet settled as to whether it will crystallize or not. There is a great deal of speculation on that subject.

MR. HERMANN:—It is an open question whether the crystalline appearance of a fracture was produced by friction, or whether it was there at the time the iron was produced.

DR. LANGLEY:—When melted steel is poured into a mould, if you break a scalded ingot it will have this appearance: (illustrating on blackboard.) I have seen ingots of this kind so fragile that by a blow of the hammer they would fall into pieces. Weak acids, will separate these crystals. But lay them into the annealing oven, and every trace of these crystals is gone, and you cannot develope them with acid, and you have the ordinary appearance of steel. If they are not crystals then certainly very profound changes can take place in internal shape.

MR. HERMANN:—Did these crystals form during the cooling?

DR. LANGLEY:—Yes, during the cooling.

A VISITOR:—What was called crystallization was tested by a professor in Cornell University, and it was eventually broken under rapid shocks.

DR. LANGLEY:—They may not be really crystals, but there is certainly proof of the change of the internal structure.

MR. BARBER:—Take a ductile substance like molasses candy, when it is suddenly struck and falls to pieces, the question is whether a like phenomenon would be observed in iron.

DR. LANGLEY:—I don't know.

MR. WARNER:—If Mr. Barber will bring the molasses candy here we we will try and enlighten him.

MR. HERMANN:—Cast-iron, when cooling, will as its color changes into black break by a single blow of the hammer into small pieces. The question s: why will iron at that temperature spatter when it will not do so while cooler or hotter?

DR. LANGLEY:—All iron is very weak at the black-red heat.

PROF. MORLEY:—There are plenty of illustrations of the fact that we haven't any real solid bodies. The objection is made that a solid body cannot crystallize. We do not know whether we have any bodies which are not capable of molecular re-arrangement. You would think glass was a solid body, but glass is constantly undergoing change due to the effects of temperature. In 5, 15, or 20 years it will have come to a permanent condition. Lately they have discovered a kind of glass in which the change is accomplished in a shorter time. But glass used for thermometers 20 years ago, the change is known to be going on for 40 years. I think iron may, under certain circumstances, undergo the

change which we call crystallization. If we want a permanent body we have to take a natural crystal which has been lying for a million years and has got to its permanent state.

MR. HERMANN:—Is it not known in chemistry that crystallization can only take place while the substance is quiet?

PROF. MORLEY:—Yes.

MR. HERMANN:—I think that the so-called crystallization in a piece of machinery takes place when the same is subjected to excessive strains starting a fracture, the surfaces of which grinding on each other, produce the polished planes that look like crystals.

THE PRESIDENT:—I have heard that men would take bars of round iron and nick around the bars and point on the side toward the man, who was holding the bar, a few blows, and drop the end off. That has been done by people who have told me of it. I would like to know whether crystallization takes place then.

MR. HERMANN:—I have seen this done with "cold short" iron, but never with red short iron, while cold.

CONSTRUCTION OF THE WOODEN PIPE LINE FOR BUTTE CITY WATER-WORKS.

BY FRED P. GUTELIUS, MEMBER, MONTANA SOCIETY OF CIVIL ENGINEERS.

[Read January 14, 1893.]

The source of the Butte City Water Company's supply is Basin Creek a stream whose source is in the Highlands twenty miles South of Butte, and whose minimum flow is three million gallons per day. After careful consideration of the several possible reservoir sites the one at the junction of Basin and Bear Gulches was selected. A description of this reservoir was recently published in the *Engineering News*. The surface elevation at this point is 5,800 feet above sea-level and about 450 feet above the old pumping station in the lower part of the City. The preservation of this head and as much additional head as could be obtained by the construction of a reservoir dam at once presented itself, and with it the use of wooden pipe, laid as near the hydraulic grade line as the undulations of the surface of the ground would permit.

Preliminary surveys in the nature of contour lines were run from the reservoir site to the Timbered Butte, two miles south of the City, which showed that the use of wooden pipe that would withstand the pressure of a 200-foot head, would be entirely practicable making a low pressure line of about nine miles, whereupon the following specifications were placed before the wooden pipe manufacturers and builders:

Specifications and Instructions for furnishing, building and completing a wooden stave water conduit for the Butte City Water Company of Butte City, Montana:—

The Water Company will do the necessary excavating and backfilling of trenches, roughly shaping the trenches to receive the conduit to the necessary shape and grade, unless otherwise specified. The contractor must furnish all material (other than herein provided that the Water Company shall supply) tools, labor etc., needed to construct and complete the conduit, and at no expense to the Water Company other than at the price and rate of price named in the contract.

All wood used in the flume must be clear stuff, free from knots, shakes and wormholes, and all other defects tending to impair the strength, durability, tightness or efficiency of the complete work. It must be truly shaped before being placed in the work. The wood must be dry, either kiln dried or air dried by standing in stack not less than two months. All staves must be properly arranged for making tight and strong end joints.

All cast iron work must be of good quality, gray iron, free from all defects and true to shape. All bands used must be of round iron or steel, uniform in diameter, with all heads truly shaped and formed, and all threads properly cut. All bands of diameter of one-half inch or greater must be upset at thread ends.

The wrought iron used must be of best quality Merchant Bar Iron. Steel, where used, must be mild homogeneous steel of about 60,000 lbs. tensile strength. The bands must be calculated on the basis of a factor of safety of four (4.)

All metal work, where possible, must be dipped before using in an acceptable quality of mineral paint or asphaltum mixture. All undipped ironwork, and all having coating removed while placing, must be well coated with said paint or asphaltum mixture after placing in position.

MAKING AND LAYING.

Furnish and place in position the cast iron special or other device for joining the stave pipe with the cast iron pipe at the reservoir end, and make joint with the casting or special to be furnished by the water company, at the North end of the stave pipe. Place in position in the line such specials, valves or other castings, with suitable hub ends to be furnished on the line by the water company. Air cocks, to be furnished by the water company, are to be placed by the contractor.

The pipe must be laid so that when completed and under pressure it shall be truly circular, true to line and curve, with bands truly spaced and fitted close to staves, and properly tightened.

The interior of pipe must be smooth, and all projecting stave ends must be replaced or dressed down. Warped staves must be rejected.

The finished pipe must be properly and carefully bedded by securely tamping earth beneath and along it up to mid-diameter. After tamping the pipe must be covered with earth to a depth of not less than 9 inches and more if needed to protect the work from the sun heat.

If the pipe is ordered laid on top of rock, earth for bedding and covering will be furnished by the Water Company at the needed locations.

All materials shall be subject to inspection and rejection at any time to the time of acceptance of the work. The contractor must guarantee the work under conditions acceptable to the Water Company, and for a period of one year from the date of acceptance, against breaks, leakage and other defects, and pay the Water Company the cost of repairs for such period.

Payments will be made monthly, on or before the 10th of each month, in cash, at Butte City, Montana, at the rate of 80 per cent. of the Engineer's estimate of work completed. The final payment will be made thirty (30) days after test and acceptance by said company, which test shall be made as quickly as possible after receiving notification of completion of the work.

Bidders will submit price per foot of completed pipe for varying pressures up to that due to 200-foot head, with tables showing diameter and spacing of bands and thickness of staves. Bids are asked for 22-inch, 24-inch and 26-inch diameter.

The right is reserved to reject any and all bids."

(Signed) BUTTE CITY WATER COMPANY,

By CHESTER B. DAVIS, Engineer.

The bid of the Excelsior Redwood Company of San Francisco was accepted.

THE LINE.

In the location of the line we endeavored to keep below and as near the hydraulic grade line, as practicable, and the deviations therefrom depended upon cost of ditch excavation and length of pipe as against cost of additional banding for heavier pressures, together with the limit of curvature which was a 24-degree curve, both for vertical and horizontal curvature. The crossing of Duffy's Gulch was the most formidable of these problems, in which it was found advisable to use iron pipe.

The cross section of the ditch was 45 inches wide on the bottom with batter of not less than 1 inch to 1 ft. The ditch was excavated 3 inches below the bottom of the pipe. Over many of the narrow gulches we made rock fills with culverts under the pipe. At these places the pipe was bedded and covered with earth and protected on the sides by means of retaining walls. In crossing running streams we invariably put the pipe beneath the bed of the stream and paved the stream bed both above and below to protect the pipe from being washed out.

There is one tunnel of 400 feet on the line. By driving this tunnel we shortened the line 3,200 feet.

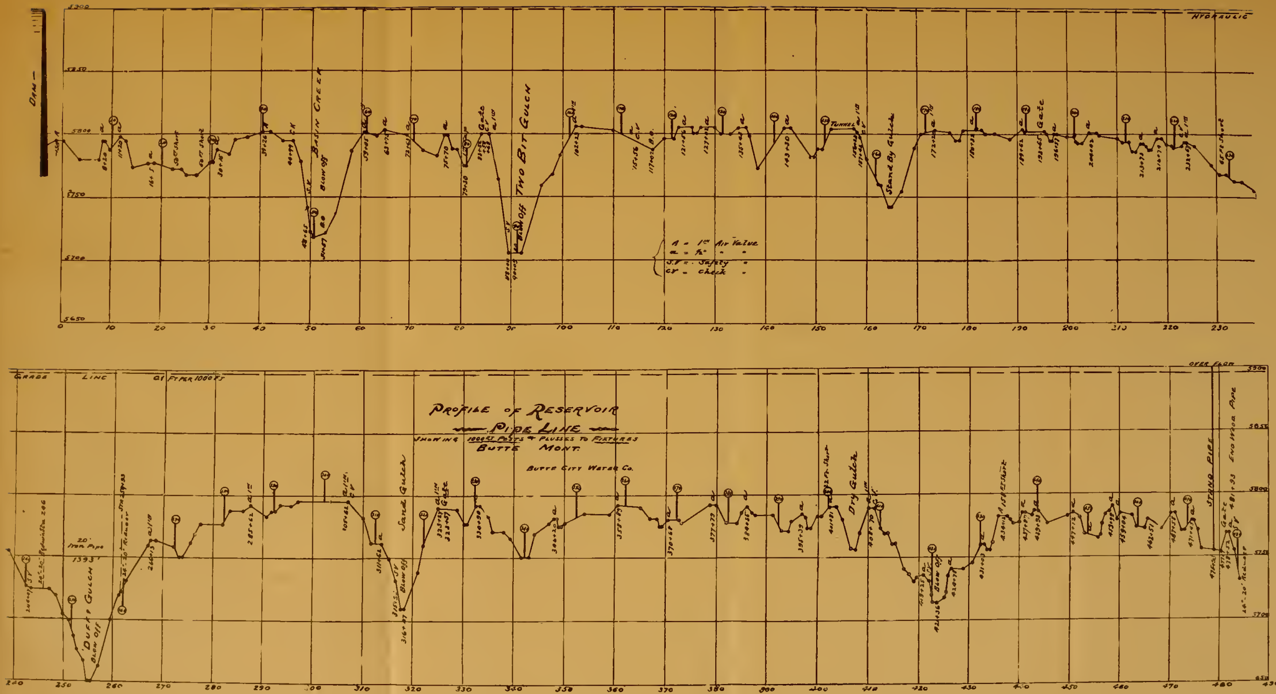
STAND PIPE.

Station 479 was selected as the best location for the stand pipe. It branches from the main pipe by means of a 24 inch "T" casting and consists of 24-inch wooden pipe laid 6 feet beneath the surface and extending up the mountain side to an elevation of 5,795 ft. above sea level, the elevation of the hydraulic grade line at this point. At the upper end of the stand pipe is built a masonry well from the wooden pipe 6 feet below the surface, after the order of a sewer manhole. Great care was taken to make a water tight joint between the pipe and the masonry. A flap valve is located just below the overflow. Upon this masonry for a foundation is built a building 6 × 6 ft., securely locked to prevent interference with these fixtures by mischievous persons.

DESCRIPTION OF PIPE.

This pipe may be considered an indefinitely extended cylindrical wooden tank. The staves are dressed like tank staves, the sides conforming to the inside and outside diameter of the pipe, the edges conforming to radial lines. Thus far the pipe and the water tank are exactly alike. The difference consists in the necessity, with pipe, of joining the butt end of the staves. Joints are generally weak places in all pipe, and it is an advantage with this pipe that the staves can be made to break joints so this weakness may not occur at the same place, but be distributed along its length; in this manner the pipe becomes one continual stiff tube, with no tendency to settle in one place more than in another. To find a sure and simple method to make the butt connections tight under pressure, Mr. C. P. Allen, some ten years ago, while Chief Engineer of the Denver Water Company, being called upon to construct a 48-inch pipe line for his company, made a series of experiments, the results of which he finally patented. It is under his patent that this pipe was constructed.

For the butt joints it was not until the simple device of inserting a piece of band iron in the end of the stave was resorted to that this problem was satisfactorily solved, using a plate cut of No. 12 band iron, one-and-one-half inches in width. The stave is slotted in the end to receive these plates. The space left for it is smaller in all directions than the plate itself. It is less in width than the thickness of the plate, so it fits snugly, and the edges of the plate penetrate the wood sidewise in the bottom of the slot, and endwise in the side of the adjoining staves. It carries the contact of stave against stave so far as water tightness is concerned, back 3-4 of an inch from the end of the stave, thus neutralizing the effect of such imperfections in the wood as do not extend further than the depth of the slot.


PROFILE OF RESERVOIR
PIPE LINE
SHOWING 100 FT POSTS & PLUSSES TO FIXTURES
BUTTE MONT.
BUTTE CITY WATER CO.
HYDRAULIC
GRADE LINE .01 FT PER 1000 FT
OVER FLOW
A = 1" Air Valve
a = ¾" " "
S.V = Safety "
CV = Check "
BASIN CREEK
TWO BIT GULCH
Stand By Gulch
TUNNEL
Gate
DUFFY GULCH
BLOW OFF
20" Iron Pipe
1393'
Sand Gulch
Dry Gulch
STAND PIPE
END WOOD PIPE

The stave is thus square at the ends, having no projecting corners which can be easily damaged. The thickness of the stave is one-and-one-half inches.

The banding of the pipe is done in a manner similar to tanks, except that round steel is used instead of flat iron bands. Herein lies the main difference between the stave pipes which have for years past been built in the East, and those which have during the last nine years been constructed in the West. A wooden pipe line that at the time attracted considerable attention was built by Mr. Fanning for the water works at Manchester, New Hampshire, for water power purposes. It is six feet in diameter, banded with flat iron. It was built in 1874 and is described in his treatise on Water Supply Engineering.

The round form of band is advantageous inasmuch as the life of the pipe is that of its shortest lived parts, which are the bands, although it is of course possible to replace old bands by new ones without abandoning the wooden shell. Now the circular cross section of the band has a maximum area with a minimum circumference, and thus offers the least possible surface to corrosive influences. Besides, the round form offers special facilities for joining the ends so they can be tightened with a single nut.

The rods are, before being bent, simple, straight half-inch bolts with a square head at one end and a thread and nut at the other, upset to 5-8 inch where thread is cut, and 3 to 5 inches longer than the outside circumference of the pipe. They were bent on the work on bending tables and then dipped in mineral paint and hung up to dry, several days ahead of the work of pipe laying. The ends of the rods are joined together by means of a maleable iron shoe of a simple form. They are shaped to fit the outside surface of the pipe. In each there is a shoulder for the head and one for the nut, the threaded end being made to lie over the head. Thus the strains on the shoe are not only as much as possible compressive strains, but they are all through the centre line of the shoe, producing no tendency to twist.

CALCULATION FOR STRENGTH.

To properly decide upon the diameter and spacing of the bands we must understand the exact purposes for which they are used.

There is an initial strain on the band when tightened, equal to the compressive strain in the wood. This strain is increased as the wood swells when water is let into the pipe. The additional strain due to this cause, however, can never attain great proportions, as it increases very gradually and is kept in check by the simultaneous adjustment of the fibre of the wood under the band. For this pipe we had to consider the bursting strain. No matter whether the shell be a mere coating of tar or asphalt or a lining of cement or wooden staves, a certain area of iron or steel is required on the outside to re-

sist these strains, and in the case of wooden pipe it remains to so divide it over bands of the right diameter, that the staves may receive support with sufficient frequency to prevent excessive deflection between the bands, and excessive indentation of the wood at the bands.

The distance between the bands, allowing a factor of safety of four, was adopted in formulating the following table of banding:

The table shows the number of bands per 100 feet of pipe for the different pressures, designated in feet of head:

24-INCH PIPE.

60 to 70 feet head,	152 bands per 100 feet.
70 " 80 " "	174 " " " "
80 " 90 " "	195 " " " "
90 " 100 " "	217 " " " "
100 " 110 " "	239 " " " "
110 " 120 " "	260 " " " "
120 " 130 " "	282 " " " "
130 " 140 " "	304 " " " "
140 " 150 " "	326 " " " "
150 " 160 " "	347 " " " "
160 " 170 " "	369 " " " "
170 " 180 " "	391 " " " "
180 " 190 " "	412 " " " "
190 " 200 " "	434 " " " "

CONSTRUCTION.

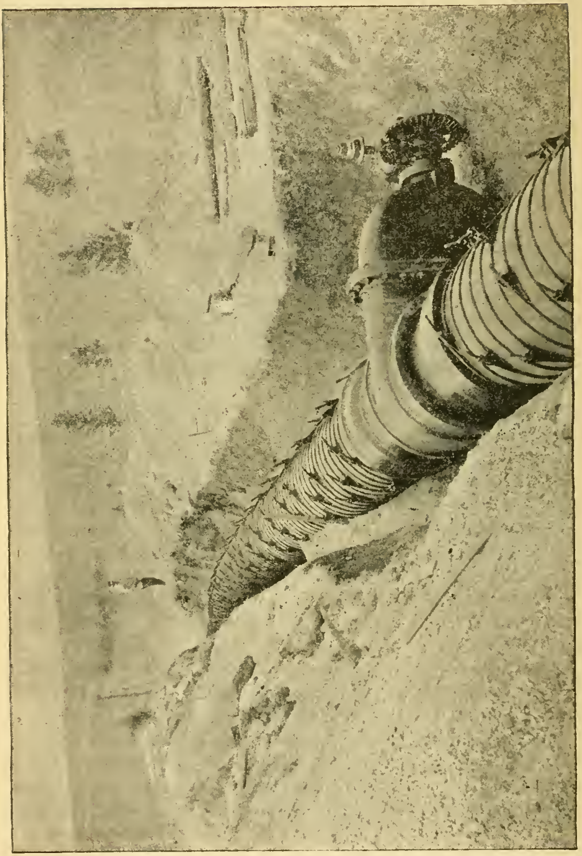
Semi-circular cradles of bent gas pipe were put on 2-inch blocks in the bottom of the trench, and in these were laid the staves forming the lower half of the pipe. Then inside forms were put in position on which were placed the balance of the staves, completing the circles. (Shown in cut No. 1.)

The staves were so placed that the end of one stave projects beyond, or falls back, 12 to 24 inches from the ends of the adjoining staves so that the end of the pipe, during construction, presents a jagged appearance. The bands were then put on and tightened whilst the pipe was rounded out from the inside.

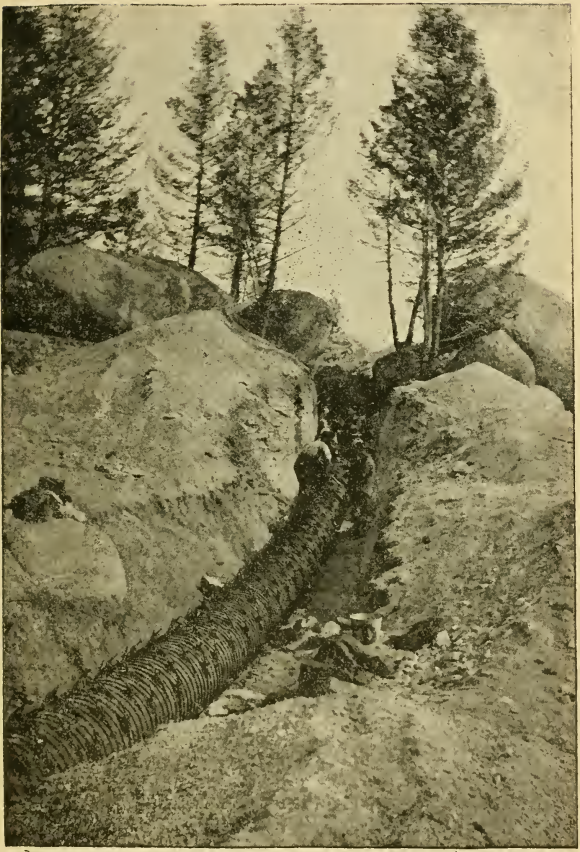
After all bands were put in place at the proper distances and were securely cinched, this first section of pipe was ready to be extended in both directions. The clips or metallic tongues were put in the slots and the staves of the next section were put in place using cradle and inside form as before. The bands were put on and while they were being tightened the staves were driven up with a heavy sledge. The pipe builders were followed by back cinchers who gave the final cinch to the bands. They in turn were followed by back fillers who tamped the earth under and along side the pipe, and covered it. In this way one gang of twelve men built from 75 to 250 feet per day. Six to ten gangs were kept at work and where they met buckles were made by fitting the staves and springing them in. (See cut No. 4.)

Connection with iron pipe and gates was made by means of special

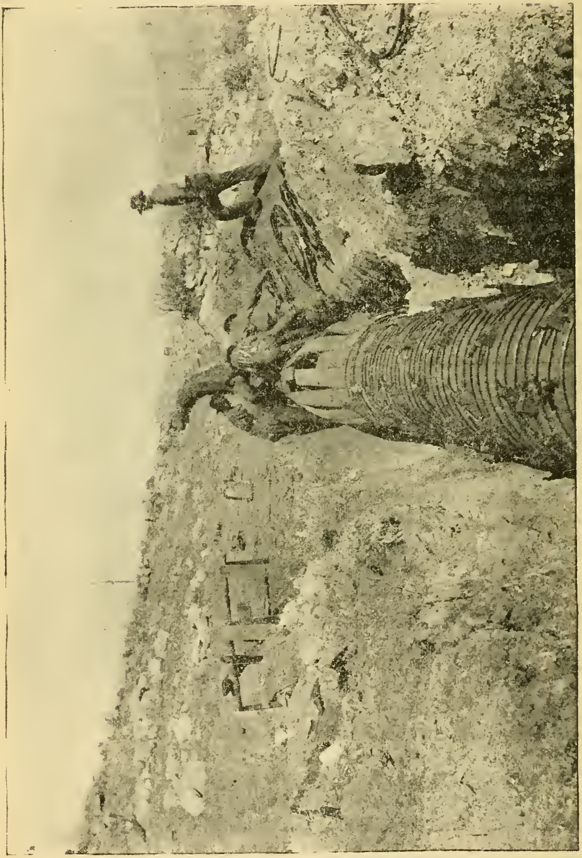
No 1. Station 354 Pressure 112 ft. Spacing 4¼ in.



No. 2. 24 in. Gate. Station 325 + 16.



No. 3. Station 343 + 50. Pressure 138 ft. Spacing 3½ in.



No. 4. Station 441 + 30. Buckle C_2.

spigot and bell castings having large and deep bells into which the wooden pipe enters. The space between pipe and bell was caulked with oakum dipped in paint. (See cut No. 2.)

There are air and check valves at all summits on the pipe line for the emission and admission of air, and safety valves where pressure is liable to be excessive. The nipples for these valves are screwed into a hole in the wood, bored with a smooth cutting bit or auger, using lock nuts and oakum packing in connection with the nipples.

There are on the line five 8″ blow-offs. These are special castings, which are virtually a 24″ × 8″ "T's" with water lines on same level.

Four 24-inch gates are located at convenient places along the line to be used in case of a break in the line or at times when repairs should be necessary.

It was found advisable to cross Duffy Gulch by means of iron pipe since the pressure on this short line exceeded the 200-ft. limit of head allowed by the wooden pipe, whereupon 1400 feet of iron pipe was used.

It is surprising how easily this pipe can be made to follow, in a general way, the undulations of the ground, although the curvature to which it can be laid is of course, limited. This pipe readily follows curves of a radius of 200 feet.

CARRYING CAPACITY.

To my knowledge no accurate measurements have been made of the carrying capacity of wooden stave pipe. We used the Kutter formula, putting the co-efficient of roughness at 0.010, which Kutter, for open flumes of well dressed timber, states to be 0.009. A test made several days ago showed this calculation to be practically correct.

Since it presents no joints or rivet heads to the current, and is otherwise perfectly smooth, it is plain that its carrying capacity must be greater than that of sheet iron or steel pipe, and that it greatly exceeds that of cast iron pipe. The inside remains smooth and clean and there need be no fear of the capacity diminishing.

CHANGING FROM 16 TO 15 STAVES.

More than three-fourths the entire line was built using 15 staves. It was found necessary, however, on account of the company's inability to furnish sufficient dry lumber of this size, to make the staves smaller, using 16 staves in the circle instead of 15, as heretofore.

At several places it was necessary to make this change in the continuous wooden pipe instead of at the cast iron specials. In order to do this it was necessary to taper one of the narrow staves to a point.

This being gradual, the tapering extended back about ten feet. In this ten feet it was necessary also to taper each of the wide staves down to the width of the narrow ones. After this was done, by means of springing these special shaped staves into place, we not only pre-

served the cylindrical shape of the pipe, but made a thoroughly water tight connection of the two sizes of staves.

The only other special shaped staves that were used on this work were the reducers at each end of the pipe. These reducers were made to fit into the hub ends of the special castings for connection between the wooden and iron pipes. The iron pipe being 20 inches in diameter, the wooden pipe was reduced to this size where it entered the hub end of the casting. The staves were tapered within a distance of ten feet to fit into this casting.

TESTS.

After the pipe was completed and water let into it, a special test was made by means of the pumps, at the old pumping station, by which the pressure was raised to that which it will be required to sustain when the reservoir dam is complete.

There were a few small leaks which were readily stopped by means of narrow wooden wedges driven into the leaky joints. The pipe has been in use since November 1st, and no further leaks have occurred.

KIRTLAND FARNUM BOOTH.—A MEMOIR.

By E. L. Corthell, H. C. Draper, Richard P. Morgan, Committee, Western Society of Engineers.

Kirtland F. Booth, the son of the Rev. Chauncey Booth, was born at South Coventry, Conn. Jan. 16, 1829, and died in the city of Chicago, March 23rd, 1892, aged sixty-three years. Mr. Booth's early life was spent working on a farm in the summer, and attending school in the winter, at Ellington, Conn., and Willston Seminary at East Hampton, Mass. Early in the year 1851, he joined the Engineer Corps in the survey and construction of the Vermont Central R. R. at Brattleboro, Vermont. While at work there he made the acquaintance of the late R. B. Mason, who was at that time the Chief Engineer of the Illinois Central R. R., and engaged to go west and work for him. He arrived at LaSalle, Ill., June 1st., 1851, having travelled west by way of the Lakes and the Illinois and Michigan Canal, and commenced work on the surveys and construction of the Illinois Central R. R., remaining on that road till its completion.

After leaving the Illinois Central R. R., he became County Surveyor of Lee Co. Ill., and lived at Amboy several years; while living in Lee County in 1853, he was married to Miss Eugenia D. Searles, who, with a married daughter survive him. From 1853 to 1865 we have no record of his work. In 1865 he began work on the Chicago & Alton R. R., under Mr. Octave Chanute, then Chief Engineer. Jan.

1st. 1867, Mr. Chanute resigned, and upon his recommendation Mr. Booth was appointed Chief Engineer, which position he held up to the time of his death. During his time he superintended most, if not all the work which has brought the Alton to be one of the best roads in the country. He was a life member of the Western Society of Engineers, having attended the first meeting of twelve gentlemen who met to organize the Civil Engineer's Club of the Northwest, in 1869.

Mr. Booth was a man of pleasing address, of unimpeachable integrity, upright and honorable in all his dealings, and a man most loyal to the interests of his employers.

In his death, the Railroad Company for which he worked lost a valued employee, and this Society a useful member.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

BOSTON SOCIETY OF CIVIL ENGINEERS.

ANNUAL DINNER.

March 7, 1893:—The eleventh annual dinner of the Boston Society of Civil Engineers was served at Young's Hotel, Boston, at 6 o'clock P. M., 129 members and guests being present.

President Henry Manley, sat at the head of the table having on either hand as guests of the Society, Prof. William H. Burr, of Harvard University, Hon. Henry W. Swift, Chairman, Harbor and Land Commissioners, Mr. George A. Perkins of the Mass. Highway Commission, Mr. Sylvester Baxter of the Metropolitan Park Commission, Col. A. A. Pope, Mr. E. P. Dawley of Providence and Mr. F. M. Twombly, President of the N. E. Railway Club.

President Manley in addressing the Society at the conclusion of the banquet, welcomed the guests of the evening and congratulated the members upon the prosperous condition of the Society. He thought the outlook for engineers was never brighter, with numerous schemes now under consideration, for rapid transit, metropolitan sewerage and better highways, there seemed to be a greater demand for engineers than ever. In closing he spoke of the engineering schools of the country and introduced Prof. William H. Burr.

Prof. Burr spoke of the work of the Lawrence Scientific School at Harvard and of the new courses in mechanical, electrical and structural engineering which had been developed during the last year or two. He felt that the school was doing good work and was a credit to the University.

Hon. Henry W. Swift was the next speaker. He referred to the pleasant associations existing between the Board of Harbor and Land Commissioners and the engineers, and spoke of the great achievements of engineers in the way of magnificent buildings, bridges and other structures.

Col. A. A. Pope spoke of the debt that civilization owes to the engineer and instanced the building of the great railways which have brought San Francisco as near to Boston as was New York when he was a boy. He then went on to describe his efforts during the past fifteen years to improve the highways of the country. He showed that good roads were conducive to increased business, that the most prosperous cities were those which had the best roads. He referred to the efforts that had been made to secure an appropriation from Congress to build up the roads of the country and also to the big petition, over a mile long, that had been presented to the national legislature, favoring better highways. He closed with an earnest plea for Massachusetts to lead in this work of liberating the country from the bondage of bad roads.

Mr. George A. Perkins said that he could not tell his hearers anything about road building, that they were the experts in the matter. The high-

way commission was established to find out the condition of the roads of the state, not how to build them. He alluded to the deplorable condition of the highways of the state, and showed that 20 per cent. of the towns of the commonwealth were appropriating less than $1000 for their roads. The only way, he asserted, to secure the desired improvement was to have the state build the roads, which shall be known as state highways. The bill that the commission has before the Legislature provides for a permanent commission that shall not only superintend the construction of roads, but shall also maintain them.

Mr. Sylvester Baxter, Secretary of the Metropolitan Park Commission argued that parks were a necessity of modern civilization. The beauties of Boston's suburbs should be preserved, he said, not only for their great natural beauty, but also in consideration of the commercial value that they represent. The speaker explained in general the park commission's exploitation of a vast forestry about Boston, and then proceeded to a consideration of the Charles river problem, which he claimed was a most important one; that if something is not done in the immediate future, realty values would suffer untold millions. He hoped the Society would give the matter its earnest and careful consideration.

Mr. E. P. Dawley of the N. Y. N. H. & H. R. R., spoke of the great improvement in railroad work in the last few years particularly in the line of signalling. He also gave a short account of what had been done to improve the railroad terminals in Providence.

President Manley then called upon Mr. Desmond FitzGerald to speak of the Society of twenty years ago. And Mr. FitzGerald responded with reminiscenes of the re-organization of the society in 1873. Mr. L. F. Rice responded for the engineer and architect and Mr. W. E. McClintock for the Massachusetts Highway Association, which closed the speaking of the evening.

Annual Meeting, March 15, 1893. The annual meeting of the Society was held at its rooms, 36 Bromfield street, Boston, at 7:40 o'clock. President Manley in the chair. Sixty-three members and ten visitors present.

The record of the last meeting was read and approved.

Messrs. Laurence B. Manley, Asa M. Mattice, Arthur D. Ropes and Ernest P. Whitten were elected members of the Society.

The Secretary read the annual report of the Board of Government which was accepted.

The tellers of election for officers asked for instruction in relation to counting twelve ballots which were not enclosed in the inner or white envelopes, and one which was not endorsed with the member's signature, but had his name stamped thereon. The meeting instructed the tellers to count the twelve ballots and to reject the one which was not properly endorsed.

The Treasurer read his annual report which was accepted. The Secretary read his annual report which was also accepted.

Prof. Burton read the report of the Committee on Weights and Measures which was accepted and ordered to be printed.

Mr. Hodgdon for the tellers appointed to canvass the letter-ballots for officers, announced the result of the ballot. There being no election for Vice-President and Librarian, the meeting proceeded to choose between the two candidates for each office having the highest number of ballots.

As the result of the letter-ballot and choice of the meeting, the following were declared elected:

President, John R. Freeman.

Vice-President, (for two years) George F. Swain.

Secretary, S. Everett Tinkham.

Treasurer, Edward W. Howe.

Librarian, Henry F. Bryant.

Director, (for two years) Henry Manley.

The recommendation of the Board of Government in its annual report was then considered and it was voted unanimously: That an assessment of one dollar be levied on members and associates of the date of March 15, 1893.

Verbal reports were made for the Committee on National Public Works by Mr. McClintock and for the Committee on World's Fair Exhibit by Mr. Freeman, which were severally accepted.

The Secretary read the report of the Committee on Permanent Headquarters which was accepted.

The reports of the Committee on Excursions and on the Library were read and accepted.

On motion of Mr. Stearns it was voted, that the continuance of the several special committees and the selection of the membership thereof, be referred to the Board of Government with full powers.

The Secretary read a communication from the New England Society of Naval Engineers in relation to the organization of an Engineers' Club in Boston. The communication was referred to the Board of Government with authority to act for the Society in the matter.

The subject for discussion was then taken up, the Relation of the Engineer to those with whom he comes in professional contact.

Mr. Desmond FitzGerald spoke on the relation of the engineer to his brother engineer; Mr. John W. Ellis of the engineer in Politics and as a Public Officer, Mr. W. E. McClintock, of the engineer in his relation to the Public and the Press; Mr. Percy M. Blake, on the engineer as a Contractor; Mr. M. M. Tidd on the engineer as an Expert Witness; Mr. A. F. Noyes on the engineer in his relations to his assistants; and President Manley closed the speaking with some remarks on the engineer as a man.

(Adjourned) S. E. Tinkham, Secretary.

Annual Report of the Board of Government for the Year 1892-93.

In compliance with the provisions of the Constitution, the Board of Government submits its report for the year ending March 15, 1893.

At the last annual meeting the total membership of the Society was 290; of which 283 were members, 6 honorary members and 1 an associate. During the past year we have lost 7 members; 3 by death, one by resignation and 3 by forfeiture of membership for non-payment of dues. There has been added to the Society during the year, 26 members and 1 associate, a total of 27, thus making a net gain of 20. One candidate has been elected but has not yet qualified.

The present membership of the Society is 310, of which 303 are members, 5 honorary members and 2 associates.

It is proper that a brief record should be made of the losses by death during the year; Past President and honorary member James B. Francis, who was closely identified with the Society from its organization in

1848, McGee Grant who joined in 1875, and Joseph Coulson who joined in 1888.

Ten regular meetings and the annual dinner have been held during the year. At the regular meetings the attendance aggregated 488 members and 226 visitors, a total of 714. The smallest attendance at any meeting was 50 and the largest 118, the average being 71.

The attendance at the annual dinner was 129.

During the year the following papers and discussions have been given:

March, 1892:—Address on the Progress of Bridge Building during the past 50 years, by Mr. T. C. Clarke.

April, 1892:—Solid Floors for Railroad Bridges, by Messrs. E. P. Dawley and J. A. McNicol.

Portal Bracing, by Albert H. Howland.

May, 1892:—The Compound Locomotive, by F. W. Dean.

Corrosion of Iron Structures, by J. H. Stanwood.

Memoir of Sophus Haagensen, by Committee of the Society.

June, 1892:—The Hudson River Tunnel, by Mr. Walter I. Aims.

The Tunnel Work of the Metropolitan Sewerage, by H. A. Carson.

The Tunnels on the New Croton Aqueduct, by G. S. Rice.

September, 1892:—The Gradual Abolition of the Highway Grade Crossings, by A. W. Locke.

October, 1892:—Rapid Transit for Boston and its Suburbs, by Geo. S. Rice.

November, 1892:—Notes on English Railways, by E. K. Turner.

December, 1892:—Base Line Measurements, by A. E. Burton.

January, 1893:—The Light-house System of the United States, by E. P. Adams.

February, 1893:—Work of the Massachusetts Highway Commission, by W. E. McClintock.

The interest in the meetings and in the excursions of the Society has been well maintained. The Society has established headquarters at No. 36 Bromfield Street, Room 8. An arrangement has been made by which the room is kept open to members during business hours of each day, and volunteer members have kept it open on each Wednesday evening since January 1st. Any member so desiring can obtain a key of the Secretary, giving him access to the rooms at all times; about 32 keys have been given out in this way. The lease taken by the Society includes the use of the large hall for its regular meetings.

The new room has been used to a considerable extent, and when the library is fully arranged in its new quarters and made available for easy use, it will doubtless be still more freely used.

The report of the Treasurer shows a net increase of $237.02 in the funds in his hands during the year. The extraordinary expense of fitting up and maintaining the Society headquarters for the financial year, has been paid from the funds in hand without special assessment.

The regular dues of the Society, as established by the by-laws, will not yield sufficient funds to meet the additional expense of maintaining the headquarters. The board recommends an assessment of $1.00 on members and associates of the date of March 15, 1893.

For the Board of Government,

Mar. 15, 1893. HENRY MANLEY, President.

Abstract of the Treasurer's and Secretary's Reports for the Financial Year 1892-93.

Current Fund.

Receipts.

Dues of Resident Members for 1892-93, 212, at $6.00	$1,272 00
" Non-Resident Members for 1892-93, 62, at $4.00	248 00
" Non-Resident Member for 1892-93, 1	1 25
" Resident Members for 1893-94, 2, at $6.00	12 00
" Non-Resident Members for 1893-94, 5, at $4.00	20 00
" New Members	120 00
Interest on Deposits	13 97
Cash at beginning of year	483 74
	$2,170 96

Expenditures.

Association of Engineering Societies for Journals	$ 902 00
Printing, Postage and Stationery	307 59
Periodicals and Binding	22 86
Rent and Janitor	237 22
Furnishing Society's room	93 85
Expenses of meetings, stenographer and lantern	51 50
Expense of moving to new room	22 50
Secretary's salary	200 00
Annual dinner	43 50
Insurance	25 20
Transferred to Permanent Fund	200 00
Cash on hand	64 74
	$2,170 96

Permanent Fund.

Receipts.

Cash at beginning of year	$ 928 78
Twenty-seven entrance fees	270 00
Interest and dividends	176 22
Transfer from current fund	200 00
Partial payment on mortgage note	700 00
	$2,275 00

Expenditures.

Shares in Merchants' Co-Operative Bank	$1,360 00
Cash on hand	915 00
	$2,275 00

Schedule of Funds of Society, March 15, 1893.

One Republican Valley R. R. Bond, par value	$ 600 00
Nine shares C., B. & Q. R. R. Stock, par value	900 00
Mortgage on real estate	800 00
Twenty-five shares Merchants' Co-operative Bank	1,369 80
Cash on deposit, Permanent Fund	915 00
Current Fund	64 74
	$4,649 54
Schedule presented at last annual meeting	4,412 52
	$ 237 02

The Treasurer has also on deposit $557.46 for Chicago Headquarter's Fund.

Report of Committee on Weights and Measures.

Mr. President:—Your committee has decided to submit as their report at this time, a brief chronicle of some of the events which have come to

their notice during the past year in connection with the adoption of new standards of weights and measures by different sections of the civilized world.

The first item of news is from a New York daily of July 18, 1892.

Washington, July 18.—Acting on information from the United States Consul-General at Paris, and the United State Consul at Lyons, the Secretary of the Treasury has requested the Secretary of State to instruct United States consular officers to refuse to certify invoices of goods consigned to the United States on and after September 1, unless the merchandise is invoiced in accordance with the metric system. He says the use of the "aune" system of measurement now employed in France on invoices of goods to the United States facilitates frauds on the customs revenue, and that the use of the metric system would simplify commercial transactions and aid materially in getting an intelligent comparison of invoices and invoice prices.

On Nov. 22, 1892, Prof. T. C. Mendenhall, superintendent of United States Coast and Geodetic Survey, and also superintendent of Weights and Measures, read a paper before the Society of Arts, of this city, on "The Standards of Weights and Measures Now Adopted by the United States Government." In this paper, he stated that the only official act of Congress authorizing a standard of weights and measures was that of July 28, 1866, in which the use of the metric system was authorized and made lawful throughout the United States. All other acts with reference to standards have been due to local legislation, with the exception of the single Congressional act authorizing the use of the "Troy Mint Pound" as the unit of weight in the coinage; and an implied authorization of the English yard, due to the appointment of Supt. Hassler, of the Coast Survey, to the position of superintendent of Weights and Measures, as at this time Mr. Hassler had in his possession a brass yard, with lines drawn on it, which were supposed to represent the length of the standard English yard at a temperature of 62 degrees Fahrenheit Both these standards above referred to are far from accurate when considered in the light of modern requirements, and this fact, together with the rather loose wording of the act of Congress, July 28, 1866, has induced the superintendent of Weights and Measures to use the recently received prototype meter and kilogramme of the International Bureau of Weights and Measures as the standard of reference in stating the length of our yard and weight of our pound. This comparison gives the value of the meter expressed in the terms of subdivisions of the Hassler yard as 39.37 inches, this last fraction being followed by three zeros, enables us now to state the relation between the old and new methods of length exactly, by using only four figures.

The following additional facts with reference to the progress of the metric system in foreign countries during the past two years, are taken from the printed circulars of the English New Decimal Association.

Russia has decided to begin the use of the métric system in the practice of medicine, and generally in scientific work.

Finland declared all other standards, than the metric, of weights and measures, to be illegal after Dec. 31, 1891.

The British Consular reports from Japan, Alexandria, Egypt, and Peru state that in the importation of goods preference is given to those countries using the metric system.

On Sept. 21, 1892, the Melbourne Legislative Assembly adopted a

motion favoring a universal union for the introduction of the decimal system in monetary affairs and in weights and measures.

The Trades Union Congress of Glasgow has lately passed a resolution in favor of the adoption of the decimal system, and has directed its parliamentary committee to do their best to secure that result. (These last two items are taken directly from the February number of *The Compass.*)

The total population of the countries using the metric system at the present time is 410,767,000, according to the circular of the New Decimal Association, 1892.

At a recent hearing given to the committee of the New Decimal Association by Sir William Harcourt, Chancellor of the Exchequer, *an unfavorable opinion* was given by the Chancellor as to the expediency of a change in money values.

In the *American Journal of Science*, January, 1893, appeared an article entitled "A Preliminary Account of the Iced Bar Base Apparatus of United States Survey and Geodetic Survey," by R. S. Woodward. From this paper we learn that the results of the experiments in connection with the measurements of the base-line in Holton, Indiana, prove that the form of base apparatus known as the "Iced bar" is capable of giving a probable error in the final length of the measured line of not more than one part in five million: also that a hundred meter suspended steel tape standardized by the use of a hundred meter comparator can be used to determine the length of the line with a probable error of not more than one part in two million. The use of a hundred meter steel-tape for the measurement of base-lines in the future will undoubtedly be the result of these experiments.

It is rather an interesting although not especially gratifying fact to record here, that although our foreign mail is weighed by scales adjusted to the metric system, yet the employes still use the term ounce and from questions addressed to some of them, it seems that the difference between the value of this ounce and the ounce used in the scale of domestic service is not well understood.

As a last item in connection with changes of standard, the committee begs leave to chronicle a movement of a possibly retrograde character in the action of the Boston Society of Civil Engineers during the past year in changing from the 24 hour system of measuring time back to the common 12 hour system.

Pamphlets from the English New Decimal association have been received by the Committee through the kindness of Mr. Fred Brooks to whom the thanks of the committee are due for much of the data herein given.

ALFRED E. BURTON,
LOUIS F. CUTTER,
HENRY A. PHILLIPS, } Committee.

REPORT OF COMMITTEE ON LIBRARY.

BOSTON, MARCH 15, 1893.

To the Boston Society of Civil Engineers:—

Last fall the Library was moved from the American House where it had been located for some years to our present quarters in the Wesleyan Building.

A large book-case was bought which with our old ones gives us room to arrange our present library so as to be quite accessible but allows very little room for any increase.

Nearly all the titles amounting to over 2,000 have been entered in the accession book. Considerable progress has been made towards getting the reports and pamphlets into proper condition for future use and preservation, but still much remains to be done.

The subject of a suitable catalogue has received much thought and discussion but as yet very little work has been done towards preparing one as the work of getting the books in order was of first importance. Quite a number of members have availed themselves of the opportunities to consult the books in the library and such use appears to be increasing.

This year more magazines have been subscribed for than in former years and they may all be found on the table in the Society's room, which is open daily from 9 A. M to 5 P. M.

Respectfully submitted, for the committee,

FRANK W. HODGDON, Librarian.

REPORT OF THE COMMITTEE ON EXCURSIONS.

BOSTON, MARCH 15, 1893.

To the Boston Society of Civil Engineers:—

During the past year your committee has given the members of this society nine excursions, on three of which they were accompanied by the ladies.

For the first time in seven years no arrangements were made for a summer excursion owing to the excursion planned for the previous year being abandoned on account of the very small number desiring to join.

The following is a list of the excursions made by your society during the past year, with the approximate attendance:—

May 18, 1892:—Providence, R. I., and Dean Compound Locomotive, 50 present.

June, 15, 1892:—Metropolitan Sewerage Works, Chelsea, 36 present.

Sept. 28, 1892:—Boston Park System, 48 present.

Oct. 19, 1892:—Cruiser "Marblehead" and Hydraulic Dredge of the San Francisco Bridge Co., 28 present.

Nov. 16, 1892:—Baker Chocolate Works, Milton, 35 present.

Dec. 21, 1892:—Youths' Companion Building and Pope Mfg. Co's Building 36 present.

Jan. 25, 1893:—Excursion in Boston Harbor to the Boston Light, 55 present.

Feb. 15, 1893:—Massachusetts Institute of Technology, 41 present.

Mar. 15, 1893:—Works of the Geo. F. Blake Mfg. Co. East Cambridge, 20 present.

For the Committee,

JOHN R. FREEMAN, Chairman.

WESTERN SOCIETY OF ENGINEERS.

302ND. MEETING, APRIL 5, 1893. The 302nd. meeting of the Society was held at the rooms of the Central Traffic Association, The Rookery, on Wednesday, April 5, 1893, at 8 P. M. President Robt. W. Hunt in the chair and 24 members and guests present.

The reading of the minutes of the last meeting was dispensed with.

At a meeting of the Board of Directors held March 27, in response to a letter and memorandum received from Mr. Corthell, the following resolution was passed:

Resolved, That the subject matter of the entertainment of Foreign Engineers in attendance upon the World's Columbian Exposition, be brought to the attention of the Society at its next monthly meeting.

The following was also carried:

Resolved, That from and after this date, copies of the *Journal* and Proceecings be sent only to such members as were not in arrears to the Society at the end of the year 1892.

The following were elected to membership: Messrs Wm. Gillingham Jr., and Frank Morse Button.

Applications received and placed on file: Messrs. Aaron M. Burt, Franklin L. Easley, James E. Maloney, Wm. A. Aiken, H. L. Hollis, John C. Beye.

In calling the attention of the Society to Mr. Corthell's letter and memorandum, the President spoke of the suggestion that the Western Society should take the lead in calling a meeting of resident members of all the different Societies, which would make the entertainment Committee more general, and bring into the fund more money. Mr. Corthell had seen a number of prominent railroad officials who had expressed themselves very favorably, and the President detailed an interview he had had with Vice-President Haines of the American Traffic Association, from which he expected that unusual facilities would be accorded from the fact of Mr Haine's cordial participation in the premises.

The President drew attention to the death of Mr. Joseph Watson, member of the Society, which occurred at Coldwater, Michigan., February 5, 1893.

Mr. Isham Randolph offered a resolution to appoint a committee to take charge of the Hospitality Fund previously called for to entain foreign visitors, and to expend same in promoting the object in view. Committee to consist of twelve gentlemen whom he named.

Mr. C. L. Strobel discussed the resolution and moved as an amendment: That the President be empowered to appoint a committee, and that it shall consist of five members, and shall have the power to add to its number.

The motion as amended was carried.

In accordance with the above resolution, the President has appointed the following gentlemen on Committee on entertainment, all of whom have accepted: Gen. Chas. FitzSimons, Isham Randolph, J. F. Wallace, Hosea Webster, John Lundie.

Mr. Morrison moved: That the communication of Mr. Corthell, dated March 22, be referred to the committee, the authority for the appointment of which has just been made, and that the committee be empowered to take such action as it may see fit in this connection.

The attention of the Society was called to the appointment of Mr. Max E. Schmidt, C. E., as Secretary of the General Committee of the Associated Societies of the United States and Canada, and also of the General Committee of the World's Congress Auxiliary on International Engineering Congress.

Until May 1, Secretary Schmidt's address is in Mr. Corthell's office, room 902; The Temple, Chicago. After May 1, his address will be at the Headquarters of the Joint Societies, third floor, No. 10, Van Buren Street.

There being no further business, the paper of the evening on the "Hydro-Geology of the Upper Mississippi and Western Lake Michigan Valley," was read by Mr. Daniel W. Mead.

The paper was illustrated with wall maps, and a printed map and profile which was distributed.

Adjourned. JOHN W. WESTON, Secretary.

ENGINEERS' CLUB OF ST. LOUIS.

381ST MEETING, APRIL 19, 1893. The club met at 8 p. m. at the club rooms. President Moore in the chair, and twenty-two members and two visitors present.

The minutes of the 380th meeting were read and approved.

Prof. Johnson reported for the entertainment committee, and said the question of finances had been brought up and that the views of the club were desired.

Upon motion it was decided that a finance committee of three be appointed to solicit subscriptions. The President appointed Messrs. Meier, Ayer and Johnson.

Capt. Carl F. Palfrey then gave the paper of the evening on "Three Reconnaissance Maps in the Latter Part of the Last Century, as Compared with the Maps of the Mississippi River Commission." The paper was an interesting discussion of the changes in the river for the last century. The old maps, while containing some errors, were, on the whole, remarkably accurate.

Discussion followed by Messrs. Ferguson, Seddon, Blaisdell, Baier, Johnson, Moore and Ockerson.

On motion a vote of thanks was given Capt. Palfrey for his interesting and valuable paper.

Adjourned. ARTHUR THACHER, Secretary.

MONTANA SOCIETY OF CIVIL ENGINEERS.

APRIL 8TH, 1893. The regular monthly meeting of the Montana Society of Civil Engineers, was held April 8, 1893, at the office of Messrs. Sizer & Keerl, at 7:30 P. M.

The following members, Haven, Beckler, Herron, Cumming and Foss, and one visitor were present.

Minutes of the previous meeting were read by the Secretary and approved.

Application for membership in the Society from Henry C. Relf, Division Engineer of the Northern Pacific Railroad, was received and referred to the Trustees.

The trustees reported favorably on the application of Albert Moog for membership. Messrs. Herron and Foss were appointed tellers to canvass the vote for the proposed amendment to the constitution and reported the same as carried there being 20 votes in the affirmative and none in the negative. The amendment was as follows:

ARTICLE II.

SECTION 6. Any member of any other Society in the Association of Engineering Societies, in good standing, may become a member of this Society, when duly elected as described in Art. 4 of the By-Laws, without paying the initiation fee, and with a release from the annual dues for such period, not over one year, as he may show by certificate he has paid in advance in the Society from which he comes.

A communication from Max E Schmidt, Secretary of the General Committee of Engineering Societies of the Columbian Exposition, asking for a list of the important engineering works and industiies in Montana, was read. The Secretary was instructed to communicate with the Managers of Mines and Smelting works in Montana and prepare the list, as requested.

Mr. A. E. Cumming read an interesting paper on the West Gallatin Irrigating Canal, giving the history of its construction and a full description of the work. Mr. Cumming said that his experience had led him to believe that about one and one-quarter miner's inches of water per acre were required for proper service for irrigation in Montana. In the discussion which followed the reading of Mr. Cumming's paper, President Haven said he had recently measured the amount of evaporation from a reservoir in Teton County, having a surface area of 46 acres and an average depth of 12 feet. No water had been drawn from the reservoir for one year and none supplied except by rainfall. There was little seepage and the total evaporation for the year amounted to 10 inches.

No further business offering, the Society, upon motion, adjourned.

G. O. Foss, Secretary.

THE CIVIL ENGINEERS' CLUB OF CLEVELAND.

April 11th, 1893. The regular meeting was held April 11th, with President Porter in the chair and about fifty members and visitors present.

The following Calender was arranged for the coming year:—

1893.	May 9th,	Architecture,
	June 13th,	Railroad Engineering,
	July 11th,	Electrical Engineering,
	Aug. 8th,	Civil Engineering and Surveying,
	Sept. 12th,	Mechanical Engineering,
	Oct. 10th,	Applied Science,
	Nov. 14th,	Marine and Steam Engineering,
	Dec. 12th,	Hydraulic and Sanitary Engineering,
1894.	Jan. 9th,	Electrical Engineering,
	Feb. 13th,	Civil Engineering and Surveying,
	Mar. 13th,	Annual Meeting,
	Apr. 10th,	Applied Science.

Messrs. M. E. Rawson, C. W. Paine and I. M. Wolverton were appointed a Committee to assist in making arrangements for the coming meeting of the Ohio Society of Surveyors and Civil Engineers.

Mr. C. F. Uebelacker then read a paper on "Electric Railways" The paper was discussed by Messrs. John W. Langley, C. W. Foote, J. Leon Gobeille, A. H. Porter and Ludwig Herman.

Frank C. Osborn, Secretary.

ASSOCIATION OF ENGINEERING SOCIETIES.

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This Association, as a body, is not responsible for the subject matter of any Society or for statements or opinions of any of its members.

A COMPARATIVE TEST OF TWO TYPES OF SMOKELESS FURNACES.

By JOHN C. McMYNN, M. M. E., BEFORE WESTERN SOCIETY OF ENGINEERS.

[Read February 1, 1893.]

The subject of Smoke Prevention has been attracting so much attention of late, and as public opinion seems to demand that the "smoke nuisance" be abated in our cities, the question which presents itself to the engineer and to the careful business man, is "How can they most economically prevent their stacks from smoking."

In attempting to solve this problem for a prominent business firm in this city, the writer made a comparative test between two so called smokeless furnaces, both placed under Horizontal Tubular Boilers, the results of which seemed of sufficient interest to warrant their presentation before the Western Society of Engineers.

A brief description of the boilers seems appropriate before giving the results of the test.

DESCRIPTION OF BOILER "A" AND FURNACE.

Boiler "A" consists of a Horizontal Tubular Boiler 60″ × 16′, and has 46—4″ tubes.

The furnace which might be called a Reverberatory Furnace is built out 5′ in front of and extends under the boiler 18″; the roof being composed of a half circular arch, built on a decline towards the boiler. At the rear of the grate, which is set at the same angle as the arch, is a brick bridge wall about 10″ high. Openings for the admission of air, both heated and cold, to complete the combustion are placed at differ-

ent parts of the furnace, and by these the amount of air admitted can be regulated.

The furnace has a patent shaking grate, worked by a lever in front, and as the results of the test will show, this grate did its work well.

Boiler "B" is situated in a large wholesale building, and is a Horizontal Tubular Boiler 54″ × 15′ 8″ and has 44—3½″ tubes.

The grates under this boiler are the common parallel bar, having no shaking appliance, and just above the furnace doors, are placed three steam jets having orifices ¼″ in diameter. The furnace doors have openings in them to allow an admission of air.

Boiler "A" was tested with Indiana Block coal as fuel on Jan. 9th, and with Brazil Block Screenings on Jan. 10th, to determine the relative economy of the two kinds of fuel.

Boiler "B" was tested on Jan. 12th, with the same quality of Brazil Block screenings.

In the trial of Boiler "A", observations were taken every 15 minutes, of the boiler pressure, temperature of feed water, temperature of gases in the uptake, reading of the meter, readings were taken on the draught gauge at frequent intervals, which were nearly constant.

All readings were taken by two observers in order to guard against errors.

In the trial of Boiler "B" the same observations were made, and in addition, the pressure in the steam jet was noted, so that the amount of steam, so used, could be calculated by means of Napier's Theorem.

The following tables contain the results of the three trials:—

Inasmuch as the test was a comparative one, I will summarize the results of fuel used and water evaporated.

Boiler "A" burned 706.5 lbs. of screenings per hour, or 47.1 lbs. per sq. ft. grate per hr. Boiler "B" burned 576.3 lbs. of screenings per hour, or 30.33 lbs. per sq. ft. of grate per hr. An excess in favor of Boiler "A", of 16.77 lbs. per hour per sq. ft. grate or 55 per cent.

Taking the Combustible, Boiler "A" consumed 67 per cent. more per sq. ft. grate per hr. than "B", and since the fuel was the same in each case, this increase of 12 per cent. can only be accounted for in part, by the superiority of one grate over the other, combined with more careful firing; as in the first case, nothing but ash came through, while in the other, live coals were noticed burning in ash pit after each cleaning; and in part by loss in smoke, as will be shown later on.

Boiler "A" burning screenings evaporated 6.737 lbs. of water from and at 212° per lb. fuel, and 8.033 lbs. water per lb. of combustible.

Boiler "B" using the same fuel, evaporated 5.792 lbs. of water from and at 212° per lb. fuel and 7.377 per lb. of combustible, without deducting the amount of water that was consumed in the steam-jet

Boiler "A" evaporates 16 per cent. more water *per lb. of fuel*, and

about 9 per cent. more water *per lb. of combustible.* This difference, as I have said is due to the large amount of ash made under Boiler "B", and the unconsumed fuel, which fell through the grates and was counted as ash. This being subtracted from the total amount of fuel used, made the combustible a smaller quantity.

Referring to Table 4, in which no correction has been made for moisture in the fuel, but the amount of steam used in the steam-jets under Boiler "B" has been deducted, we see that Boiler "A" evaporates from and at 212°, 6.737 lbs. of water per lb. of fuel, while Boiler "B" evaporates 5.533 lbs., showing an increase in favor of Boiler "A" of 26 per cent.

It is from this last comparison that we can figure relative costs, for the moisture in the fuel must be paid for, whether it be an advantage or a detriment, and the steam used in the jet should be deducted from the evaporation, as it is not available evaporation.

To reduce the foregoing results of evaporation per lb. of fuel, to dollars and cents, which medium appeals to "all men at all times," we see that this Boiler "A" burning as fuel Indiana Block Coal, costing $2.70 per ton, it costs $0.328 to evaporate 1 ton of water, while in the same boiler using as fuel Brazil Block Screenings, at $1.85 per ton it costs $0.2745 to do the same work, showing a saving of $0.0535 per ton of water evaporated, in favor of Screenings as fuel, or a saving of 16.3 per cent.

Battery "A" consists of four boilers, one of which is our Boiler "A", and these four boilers burn now about 600 tons of Indiana Block Coal, per month, as the price for this coal is $2.70 per ton the fuel bill is $1620 per month, but as we have shown that there would be a saving of 16.3 per cent., should the owner change his fuel to screenings, *i. e.* a gross saving of $264 per month; allowing $50 per month for extra help, and $60 for removing increased ash, there would be a net saving of $154 per month or $1848 per year. I make no estimate for increased depreciation of furnace, as in my limited but thorough observation, I feel sure that this furnace can burn Screenings without more than the usual injury sustained when Block coal is burned.

Now considering the two Batteries "A" and "B", using as fuel in each Brazil Block Screenings, costing $1.85 per ton:

Assuming that Battery "A" would use 700 tons of screenings to do the same amount of work that it did with 600 tons of Block Coal per month, and since "A" evaporates 26 per cent. more water than does "B" per lb. of fuel, from and at 212°, Battery "B" would need 862 tons of screenings to do the same amount of work: hence the fuel bills for the two plants would be "A" $1295 and "B" $1595 per month or a net saving of $300 per month, or $3600 per year.

Looking at these two boilers and their furnaces, from the standpoint

of an outsider, where the stacks could be seen, Boiler "A" showed only the faintest signs of smoke, and then it was only for a few seconds at a time. Boiler "B" had no compunctions in breaking the one law of the Smoke Society, "No smoking Allowed," and whenever the boiler was being pushed a little harder than usual or when the fire was low the stack showed an abundance of smoke.

These trials bring out one fact prominently, that the combustion was more complete in boiler "A" than in "B", and an increased evaporation and a decrease of smoke followed. Mr. Morris Sellers, in a valuable paper on "Combustion in Locomotives" read at Philadelphia in 1870, before the Master Mechanics Association, draws attention to the fact that, fire boxes were not rightly proportioned, to admit air at the right velocity, and in sufficient quantity to produce complete combustion. He also suggests that the way to obtain complete, and hence smokeless combustion, was to introduce brick arches and deflectors, which would create a recoil of the current, and friction, thus keeping the air and the gases in contact for a longer period and he also says, "The only radical mode of obviating these difficulties is to REGULATE the influx of air according to its requirements."

These ideas seem to have been carried out in part, in Boiler "A". In the foregoing report I have endeavored to simply give the facts, leaving opinions to older and more experienced heads than mine. However if I may be permitted I would suggest a couple of pertinent questions for discussion.

Will a steam-jet correctly applied prevent smoke?

Is smoke consumed or prevented?

FUEL CONSUMPTION AND EVAPORATION.

	Evaporation from and at 212°		
	Boiler "A" Block Coal.	Boiler "B" Screenings.	Boiler "B" Screenings.*
Per lb. fuel.......	8.237	6.737	5.333
Cost of fuel per ton......	$2.70	$1.85	$1.85
Cost of evaporating 1 ton of water.....	$0.328	$0.2745	$0.3469

* Correction made for steam jet.

Comparing the last two cases, in which both boilers burned the same quality of screenings:

It costs Boiler "B" 26% more to evaporate water than it does Boiler "A"

It costs Boiler "A" 20.6% less to evaporate water than it does Boiler "B"

Boiler "A" evaporates 26% more water per lb. of fuel.
" " " 18.2% " " " " " combustible.
" " " 28% " " " sq. ft. of heating surface.
" " " 96% " " " " " " grate surface.

These trials were conducted in as nearly the same manner, and under as closely identical conditions as possible, in order to ascertain which boiler gave the best evaporation per lb. of coal and combustible.

The fuel was carefully weighed, and the weights of each load were checked by two observers. We endeavored to supply the fire-men with just about the amount he wished to burn per hour.

The water was measured the same way in all three trials, by the Worthington Meter, which was carefully calibrated, to determine the error at the different temperatures and pressure of the feed water.

The temperature of the feed water was taken by means of a thermometer, in a light brass plug, inserted in the feed pipe. Temperature of the gases was determined by means of a pyrometer, placed in the uptake.

Quality of steam was found by a throttling calorimeter, at different times during the trail, at a point in the steam pipe, near the boiler. And in each case the steam was found to be but 1.7% wet.

All gauges and thermometers used were calibrated and corrections made when necessary.

The following tables contain the results of the three trials:—

Table No. 1.—Contains results of of Trials in parallel columns, without making corrections for the moisture in the Screenings, or the amount of steam used in the jets under Boiler "B."

Table No. 2.—Contains results of Trials 2 and 3, in parallel columns, making corrections for the moisture in the Screenings, used in Trials 2 and 3, but not taking into account the steam used in the steam-jet in Trial 3.

Table No. 3.—Contains results of Trials 2 and 3, corrections being made for moisture in fuel and for steam used in jets in Trial 3.

Table No. 4.—Contains results of Trials 2 and 3 in parallel columns, without making corrections for moisture in Screenings, but deducting the amount of steam used in Steam Jet in Trial 3.

TABLE NO. 1.

	Trial No. 1.	Trial No. 2.	Trial No. 3.
Kind of Boilers	Hor. Tubular.	Hor. Tubular.	Hor. Tubular.
Dimensions	60"×16'—46-4" T.	60"×16'—46-4" T.	54"×188"—44-3½" T.
Duration of trial	10 hrs.	10 hrs.	10 hrs.
Grate surface, sq. ft	15	15	19
Water surf., heating, sq ft.	895	895	742
Ratio, heating to grate surface	60:1	60:1	39:1
PRESSURES.			
Barometer	28.9	28.9	28.88
Steam gauge lbs. (average)	92.4	94.35	71
Draught gauge, inches	⅝"	11/16"	11/16"
Absolute pressure, lbs	107.1	109.05	85.70
TEMPERATURES.			
External air	20	18	8
Boiler room	65	63	70
Flue	571.30	540.60	522.1
Feed Water	187.30	192.20	209.37
Steam	332	334	323.30
FUEL.			
Kind of Coal	Ind. Block.	Screenings.	Screenings.
Cost per ton	2.70	1.85	1.85
Total fuel used, lbs.	6240	7065	5763
Dry coal consumed, lbs	6240	7065	5763
Total ash, lbs	392	1140.5	1238.25
Per cent. ash, lbs	6.28	18.34	21.82
Total combustible, lbs	5848	5924.50	4524.75
FUEL PER HOUR.			
Coal per hour, lbs	624	706.5	576.3
Combustible per hour, lbs.	584.80	592.45	452.47
Coal per sq. ft. grate per hr.	41.60	47.10	30.33
Comb'le " " " "	38.99	39.50	23.81
Coal per sq. ft. heating surface per hour	.6972	.7394	.7772
Combustible per sq. ft. heating surf. per hour ...	.6534	.6619	.6094
WATER.			
Total water, meter, cu. ft. (Corrected)	802.20	743	538.46
Total water, lbs	48445	44777.64	32218.21
Factor of evaporation	1.061	1.063	1.036
Total from and at 212°	51400	47598.63	33378.06
WATER PER HOUR.			
Amount used, lbs	4844.50	4477.76	3221.82
Evaporat'n from and at 212°	5140	4759.86	3337.80
EVAPORATION.			
Per lb. fuel.			
Actual evaporation, lbs	7.762	6.338	5.589
From and at 212°	8.237	6.737	5.792
Per lb. combustible.			
Actual evaporation, lbs	8.282	7.557	7.121
From and at 212°	8.789	8.033	7.377
Per sq. ft. of heating surface per hour.			
Actual evaporation, lbs	5.413	5.001	4.342
From and at 212°	5.743	5.318	4.497
Per sq. ft. grate surface per hour.			
Actual evaporation, lbs	323	298.51	169.55
From and at 212°	342.69	317.30	175.68
HORSE POWER.			
On basis 34½ lbs. per hour (Standard)	149	138	96.75
Builder's rating	75	75	62
Per cent. (Standard) over Builder's	100	84	56

TABLE NO. 2.

	Trial No. 2.	Trial No. 3.
Kind of Boilers	Hor. Tubular.	Hor. Tubular.
Dimensions	60″×16′—46-4″ T.	54″×188′—44-3½″ T.
Duration of trial	10 hrs.	10 hrs.
Grate surface, sq. ft	15	19
Water surface, heating, sq. ft	895	742
Ratio, heating to grate surface	60 : 1	39 : 1
PRESSURES.		
Barometer	28.9	28.88
Steam gauge, lbs. (average)	94.35	71
Draught gauge, inches	11/16″	11/16
Absolute pressure, lbs	109.05	85.70
TEMPERATURES.		
External air	18	8
Boiler room	63	70
Flue	540.60	522.1
Feed water	192.20	209.37
Steam	334	323.30
FUEL.		
Kind of coal	Screenings.	Screenings.
Cost per ton	1.85	1.85
Total fuel used, lbs	7065	5763
Per cent. moisture	12	11.66
Dry coal consumed, lbs	6217.2	5091.0
Total ash, lbs	1140.5	1238.25
Per cent. ash, lbs	18.34	24.32
Total combustible, lbs	5076 7	3852.75
FUEL PER HOUR.		
Coal per hour, lbs	621.72	509.10
Combustible per hour, lbs	507.67	385.27
Coal per sq. ft. grate per hour	41.45	26.79
Combus'le " " " "	38.85	20.28
Coal per sq. ft. heating surf. per hour	.6946	.6862
Comb'le " " " " "	.5672	.5191
WATER.		
Total water, meter cu. ft. (Corrected)	743	538.46
Total water, lbs	44777.64	32218.21
Factor of evaporation	1.063	1.036
Total from and at 212°	47598.63	33378.06
WATER PER HOUR.		
Amount used, lbs	4477.76	3221.82
Evaporation from and at 212°	4759.86	3337.80
EVAPORATION.		
Per lb. fuel.		
Actual evaporation, lbs	7.203	6.327
From and at 212°	7.656	6.556
Per lb. combustible.		
Actual evaporation, lbs	8.821	8.366
From and at 212°	9.375	8.664
Per sq. ft. of heating surface per hr.		
Actual evaporation, lbs	5.003	4.342
From and at 212°	5.318	4.449
Per sq. ft. grate surface per hour.		
Actual evaporation, lbs	298.45	169.60
From and at 212°	317.30	176.65
HORSE POWER.		
On basis 34½ lbs. per hour (Standard)	138	96.75
Builder's rating	75	62
Per cent. (Standard) over Builder's	84	56

TABLE NO. 3.

	Trial No. 2.	Trial No. 3.
Kind of Boilers	Hor. Tubular.	Hor. Tubular.
Dimensions	60"×16'—46—4"T	54"×188"—44—3½T.
Duration of trial	10 hrs.	10 hrs.
Grate surface, sq. ft	15	19
Water surface, heating sq. ft	895	742
Ratio, heating to grate surface	60:1	39:1
PRESSURES.		
Barometer	28.9	28.88
Steam gauge. lbs. (average)	94.35	71
Draught gauge ins	11/16	11/16"
Absolute pressure, lbs	109.05	85.70
TEMPERATURES.		
External air	18	8
Boiler room	63	70
Flue	540.60	522.1
Feed water	192.20	209.37
Steam	334	323 30
FUEL.		
Kind of coal	Screenings.	Screenings.
Cost per ton	1.85	1.85
Total fuel used, lbs	7065	5763
Per cent. moisture in fuel	12	11.66
Dry coal consumed, lbs	6217.2	5091.0
Total ash, lbs	1140.5	1238.25
Per cent. ash, lbs	18.34	24 32
Total combustible, lbs	5076.7	3852.75
FUEL, PER HOUR.		
Coal per hour, lbs	621.72	509.10
Combustible per hour. lbs	507.67	385.27
Coal per sq. ft. grate per hour	41.45	26.79
Combustible ft. grate per hour	38.85	20.28
Coal per sq. ft. heat surf. per hour	.6946	.6862
Comb. per. sq. ft. heat surf. per hr	.5672	.5191
WATER.		
Total water, meter cu. ft. (corrected)	743	538.48
Total water, lbs	44777.64	32218.21
Factor of evaporation	1.063	1.036
Total from and at 212°	47598.63	33378.06
WATER PER HOUR.—(Corre. for Steam Jet, 2636 lbs.)		
Amount used, lbs	4477.76	2958.22
Evaporation from and at 212°	4759.86	3074.20
EVAPORATION.		
Per lb. fuel.		
Actual evaporation, lbs	7.203	5.810
From and at 212°	7.656	6.039
Per lb. Combustible.		
Actual evaporation, lbs	8.821	7.679
From and at 212°	9.375	7.979
Per sq. ft. of heating surface per hr.		
Actual evaporation, lbs	5.003	3.987
From and at 212°	5.318	4.143
Per sq. ft. grate surface per hour.		
Actual evaporation, lbs	298.45	155.62
From and at 212°	317.30	161.69
HORSE POWER.		
On basis 34½ lbs. per hour (Stand)	138	90
Builder's rating	75	65
Per cent. (Standard) over Builder's	84	39.1

TABLE NO. 4.

	Trial No. 1.	Trial No. 3.
Kind of Boilers	Hor Tubular.	Hor. Tubular.
Dimensions	60" X 16'—46—4" T.	54" X 188" 44—3½" T.
Duration of trial	10 hrs.	10 hrs.
Grate surface, sq. ft	15	19
Water surface. heating sq. ft	895	742
Ratio, heating to grate surface	60 : 1	39 : 1
PRESSURES.		
Barometer	28.9	28.88
Steam gauge lbs. (Average)	94.35	71
Draught gauge, ins	11/16	11/16
Absolute pressure, lbs	109.05	85.70
TEMPERATURES.		
External Air	18	8
Boiler room	63	70
Flue	540.60	522 1
Feed water	192.20	209.37
Steam	334	323.30
FUEL.		
Kind of coal	Screenings.	Screenings.
Cost per ton	1.85	1.85
Total fuel used, lbs	7065	5763
Dry coal consumed, lbs	7065	5763
Total ash, lbs	1140.5	1238.25
Per cent. ash, lbs	18.34	21.82
Total combustible, lbs	5924 50	4524.75
FUEL, PER HOUR.		
Coal per hour, lbs	706.5	576.3
Combustible per hour, lbs	592.45	452.47
Coal per sq. ft. grate per hour	47.10	30.33
Combustible. per sq. ft. grate per hr	39.50	23.81
Coal per sq. ft. heat surf. per hour	.7394	.7772
Comb. per sq. ft. heat surf. per hour	.6619	.6094
WATER.		
Total water, meter, cu. ft. (Corrected)	743.	538.46
Total water, lbs	44777.64	32218.21
Factor of evaporation	1.663	1.036
Total from and at 21 8	47598.63	33378.06
Correction for steam jet, 10 hrs		2636.00
AVAILABLE WATER PER HOUR.		
Amount used, lbs	4477.76	2958.22
Evaporation from and at 212°	4759.86	3074.20
EVAPORATION.		
Per lb. fuel.		
Actual evaporation lbs	6.338	5.132
From and at 212°	6.737	5.333
Per lb. combustible.		
Actual evaporation	7.557	6.538
From and at 212°	8.033	6.794
Per sq. ft. of heating surf. per hr.		
Actual evaporation, lbs	5.001	3.916
From and at 212°	5.318	4.146
Per sq. ft. grate surface per hour.		
Actual evaporation, lbs	298.51	155.69
From and at 212°	317.30	161.80
Horse power (Standard)	138.	90

STEAM ENGINE EFFICIENCY—ITS POSSIBILITIES AND LIMITATIONS.

By Wm. H. Bryan, Member Engineers' Club of St. Louis.

(Read Oct. 19, 1892.)

Among the steam using public there is not a little uncertainty as to just what is meant by steam engine efficiency. And many engineers, who, in the multiplicity of their duties in other directions, have found little or no time for research in this field, are frequently mystified. We are told, for instance, that the exhaust should always be condensed; that engines using steam expansively, are better than engines with throttling governors; that double compound engines are better than single cylinder: that triple compound engines are still better; and that if we desire to reach the highest efficiency, we must use the quadruple compound engine.

These statements come from the highest authorities, who point to many instances of success; and yet we need not go far to find cases where results quite the contrary have been found—where the addition of a condenser has resulted in an increase in the coal bill; the cut-off engine has proved more wasteful than the throttling engine; the single cylinder than any form of multiple-cylinder. So signal have been the failures in some cases, that the business man, judging efficiency solely from the standpoint of dollars and cents, has felt called upon to denounce the whole idea of higher economy as laid down by the authorities, and all the improved appliances thereto. And thus another failure is recorded, and the theoretical is again claimed to be at variance with the practical.

I have had occasion before this, to discuss the relations beween theory and practice (see *Age of Steel* of June 25, 1892,) and shall not now take them up. Suffice it to say, that when such discrepancies appear we have either made a wrong application of a true theory, or, we have selected a theory which in no way fits the case in hand.

I bring to you this evening no startling or newly developed theories, no unexpected or disappointing results from practice. I cannot even claim the merit of originality or novelty for what I have to say, for the facts are all of record, and were laid down by master-minds, whose invaluable researches have made our present knowledge possible. I shall feel amply rewarded if I succeed in calling serious attention to a few principles underlying the success of the commercial steam engine, pointing out its strong features and its drawbacks, even though I may not indicate clearly the proper path to follow in any given case.

It is necessary to consider the steam engine in two aspects—the ideal and the real. The former is the perfect engine, the thermo-dynamic engine, the engine of the philosophers, of the Carnot cycle. It does not exist, never has existed, and never will exist. It has no standing in the world of practical mechanics, but it has, nevertheless, a place of great importance in the world of the student. It is this engine which tells us what is before us, and which sets a limit to our ambitions—a limit which we shall never reach, and which is still far beyond us, but which warrants our most earnest efforts in drawing nearer to it.

The conception of the ideal or perfect engine is simple. Steam considered as perfect gas expands, as many times as we choose, in a single perfect cylinder, the walls of which neither absorb nor give out heat. We measure its losses by the difference between the temperatures T_1 T_2, between which it works, and its efficiency by $\frac{T_1 - T_2}{T_1}$ measured in each case from the absolute zero, 461 degrees below the zero of Fahrenheit. An efficiency of unity is therefore attainable only by discharging the exhaust at the absolute zero of temperature—a condition now manifestly impossible, and likely always to remain so.

We see then, that the perfect steam engine itself, is of low efficiency, due to the comparatively narrow limits of temperature within which we must work. It is possible, however, to clearly determine the efficiency of a perfect heat engine working between the limits of temperature now common in practice. Cotterill, in his admirable work on "The Steam Engine Considered As a Heat Engine," states them as follows:

TYPE OF ENGINE.	Superior Limit.		Inferior Limit.		Lbs. Steam Per I H. P. per Hour.	Efficiency.
	Pressure Abs.	Temps F.	Pressure Abs.	Temps F.		
Non-Condensing..	250	401	14.7	212	11.4	.219
	160	363	"	"	13.8	.183
	120	341	"	"	15.8	.161
	80	312	"	"	19.9	.130
	55	287	"	"	26.0	.100
Condensing.......	120	341	0	100	7.5	.299
	95	324	"	"	8.1	.285
	60	293	"	"	9.0	.256
	30	250	"	"	11.2	.211
	20	288	"	"	12.8	.186

From which it appears that the perfect engine, with condenser, running with 105 pounds gauge pressure, requires 7½ pounds of steam

per horse-power per hour ; and that, even then, its efficiency is less than 30 per cent. In other words, if it were possible to transform all the heat units in the steam into useful work, but $2\frac{1}{4}$ pounds of steam per horse power per hour would be required.

It is evident, therefore, from a consideration of the theory of the steam engine, that there are drawbacks inherent in this form of motor, which set a definite limit to its economy. This has led to a wide investigation in other fields for a more efficient motor—not without some promise of success—but the many advantages and conveniences of the steam engine will, in all probability, keep it with us for many years.

Let us now take up the actual commercial steam engine of to-day.

It has many frailties. It lacks as much of attaining the efficiency of the perfect engine as the latter does of fully utilizing the heat units which, if the expression may be allowed, pass through its fingers. The apparently simple requirements of the perfect engine are impossible of attainment. Steam is not a perfect gas when saturated—and only approximately so when superheated. The number of expansions possible in practice is limited. High initial temperatures and pressures mean increase in first cost, and cost of maintenance, greater liability to accident, and greater losses through leakage. The limit in the other direction is even more rigidly fixed. A condenser temperature of 100 degrees F. is even lower than can ordinarily be obtained. It is true that Du Tremblay lowered the final temperature to 60 degrees by the addition of an ether engine, working between the temperature of exhaust steam and that of the condensation of ether, by which means he secured an efficiency of 35 per. cent. for the perfect engine. This plan, however, has not come into general use, and probably never will, on account of the practical difficulties connected with the use of ether.

Furthermore, a large number of expansions in a single cylinder, mean a very large vessel, very rigid and heavy construction, and serious losses due to internal condensation--the comparatively cold walls of the cylinder robbing the entering steam of a large number of its heat units, and giving them back near the end of the stroke, too late for transformation into useful work, and where they are swept out by the exhaust.

These difficulties have led to the development of the multiple-cylinder engine, in which the steam is worked successively through a number of cylinders in series. This has resulted in a better distribution of the strains, and, as Prof. Thurston has recently pointed out so clearly, confines the losses to those of a single cylinder working between comparatively narrow limits of temperature. The heat units

restored in the latter part of the stroke, instead of being swept away unused, are available for efficient service in the next succeeding cylinder.

Practical difficulties are soon encountered here, however. Multiple-cylinders mean greatly increased first cost for the same capacity, greater complication of parts, and as a result more liability to derangement, besides requiring a higher and better paid class of skilled labor in their operation. In addition, there is an increased cost for space and for foundations.

The real steam engine—whether simple or multiple-cylinder—is subject to still further losses. Piston speeds are confined within narrow limits; clearance spaces may be reduced, but cannot be wholly done away with; valve gears are slow in acting and imperfect; valves themselves, as well as pistons, leak; and more or less heat is lost through conduction and radiation.

And, in practice, the losses do not stop here. No engine, however well constructed and designed, ever has perfect care. Leaks occur and grow. Adjustments become less and less accurate. Steam is frequently wet. Steam passages are uncovered, and sometimes they are badly cramped. Worst of all, the work is frequently far different from that for which the engine was designed. An underload is even more fatal to good economy than an overload, but it is frequently unavoidable, as power must be provided for prospective, as well as present requirements. Furthermore, it is frequently necessary that an engine be sufficiently large to handle sudden and severe overloads, as in rolling mill and electric railway service. Here the maximum is sometimes many times the average load, so that conditions favorable to high steam efficiency are impossible of attainment.

There is one other loss which cannot be wholly overlooked in this discussion—that of the friction of the engine itself—which reduces the indicated horse-power to that known as "net effective," capable of delivery to the work in hand. This is a question wholly of design, construction, and care in operating, and is largely increased by the complication of parts necessary in multiple-cylinder, or other types of high efficiency engines.

I believe I need say no more to convince you that the conscientious engineer who would select the best engine for any given work, has a problem of no mean proportions on his hands. It is half the battle to be able to definitely and clearly state the conditions, but this is often difficult and sometimes impossible. The question comes to us in a wide variety of forms. We cannot always determine in advance what our load may be; and if we could, it is more difficult in many lines of work to determine the maximum and minimum requirements, and to give them their proper relative value as compared with the average load.

Let us assume, however, that we are able to simplify the problem to that of selecting or designing the type of engine best adapted for a given constant load, of specified duration. This leaves us free to select the initial and terminal pressures and temperatures; the general type of engine, whether single or multiple-cylinder, condensing or non-condensing; piston and rotative speed; and whether we shall jacket the cylinders, and use saturated or superheated steam.

First, it will be interesting to make some comparisons of existing engines of well-known types, to determine what efficiency is already attainable in practice, under the most favorable conditions.

EFFICIENCY OF ACTUAL ENGINES.

No.	TYPE OF ENGINE.	SUPERIOR LIMIT.		INFERIOR LIMIT.		Steam lbs. per I.H.P. per hour.		EFFICIENCIES.		
		Pressure Absolute.	Temperature F.	Pressure Absolute.	Temperature F.	Ideal	Actual	A.	B.	C.
1	Tr. Comp.	140.	353.	1.5	115.	7.925	12.67	.183	.292	.626
2	Condensing.	140.	353.	1.8	109.	7.615	12.94	.176	.300	.588
3	Cr. Comp. Con.	113.	337.	1.7	115.	8.384	13.26	.176	.278	.632
4	Tan.C'mp.Con.	111.	335.	1.7	115.	8.437	14.50	.159	.276	.577
5	Ver.Comp.Con.	117.	339.	2.	120.	8.933	14.07	.174	.274	.635
6	Corliss S. C. C.	72.	305.	4.6	112.	9.289	18.59	.126	.252	.500
7	Corliss N. C.	89.	319.	15.9	216.	19.522	25.39	.102	.132	.769
8	Locomotive.	130.	347.	20.2	228.	17.574	26.86	.096	.174	.654
9	Loco've Comp.	151.	336.	19.4	226.	15.331	20.86	.125	.169	.739
10	Slide Valve.	93.	322.	17.2	220.	19.849	32.34	.063	.103	.614

While this data is not as complete as I would like to have it, it is nevertheless worthy of study. The results given under the head of Efficiencies are particularly interesting. Column *A* indicates the efficiency of the engine as regards the total heat units in the steam. Column *B* indicates the efficiency of a perfect heat engine working between the given limits of temperature. Column *C* represents the relative efficiency, that is to say, the ratio of the heat units utilized to those available within the limits of temperature between which the engine is working.

The efficiencies shown in column *C* are of special interest, as they indicate the extent to which each type of engine utilizes its opportunities as a heat engine. The steam consumption of the ideal engine, as

shown in column 7, is the limit toward which we should continually draw nearer. The efficiencies in column C show how much our present engines lack of reaching perfection. It is not too much to expect that these efficiencies may be continually improved in time by improving types of engine, as the losses may all be termed preventable, at least in very large part.

Considered wholly as heat engines, the complicated "High Efficiency" machines are less efficient than engines of simpler construction. This is as might be expected, on account of the fewer opportunities for leakages and other losses.

A curious fact is shown by test number 7. The ordinary single cylinder, non-condensing engine, which has a theoretical efficiency of less than half that of the triple expansion engine, appears in the present instance to have a relative efficiency very much greater.

No. 1 is the triple compound vertical condensing pumping engine of 15,000,000 gallons capacity daily, at the Harrison Street pumping station, Chicago. The test was made by B. H. Feind, assistant city engineer.

No. 2 is a horizontal triple compound condensing engine in the plant of the Narragansett Electric Lighting Co., Providence, R. I. This test was made by E. D. Leavitt.

No. 3 is a cross-compound engine in the mills of the Richmond Manufacturing Co., Bristol, R. I. The test was made by Remington and Henthorn, engineers, Providence, R. I.

No. 4 is a tandem-compound condensing engine in the works of the Plymouth Cordage Co., Plymouth, Mass. This test also, was made by Mr. Leavitt.

No. 5 is a vertical compound condensing engine. All the above engines were built by the Edward P. Allis Co., Milwaukee.

Nos. 6 and 7 are from tests made in 1877 by John W. Hill on an 18×42 Harris Corliss, speeded 75, located in the flour mill of Gibson & Co., Indianapolis, Ind.

Nos. 8 and 9 are from Baldwin locomotives on the Baltimore & Ohio Railroad, the tests being made by George H. Barrus in 1890. No. 9 is the only authentic record I could find, of a non-condensing compound engine, but I think the results fairly represent what may be secured from similar stationary engines.

No. 10 is from a well designed slide-valve engine, 40 horse power, 9×15.6, speeded 195, tested at the Sixth Cincinnati Industrial Exposition in 1875, by John W. Hill, Isaac V. Holmes and J. F. Flagg. The results are undoubtedly much better than can be secured from the ordinary slide-valve engine, which rarely falls below forty pounds steam per I. H. P. hour. In fact, the results given may be taken as

fairly representative of the best high speed automatic cut-off engine practice of the present day.

High efficiency is evidently a question of cost, both in plant and skilled attendance. High duty engines, with the necessary high pressure boilers and pipe work, are expensive at first, and difficult to maintain. The problem then appears to be, not what is the highest efficiency possible, but how high an efficiency can we afford.

I shall not attempt to answer this question in detail. It is a complicated one, and can only be definitely settled by a special consideration of the peculiar features surrounding each case.

The important advantages to be gained by the use of high effiiciency engines are:

1st.—Reduced fuel bills; and 2d—Reduced first cost for boilers, with their settings, and the space they occupy, there being fewer of them required.

As the second consideration is usually much more than off-set by the increased cost and space occupied by the engines; we may reduce the problem to that of the net saving in fuel, and its value in dollars and cents. By the later standard must all such problems be judged. The most ordinary slide-valve engine is amply effiicient at the mouth of a coal pit, while in distant mountain regions, where fuel is very costly, the highest grade of multiple-cylinder condensing engines are usually justified. This conclusion, however, must be modified in any particular case by the surroundings. Is water available at reasonable cost, for condensing? Can skilled attendance be had; is the engine of a complicated nature, liable to accident, and difficult and expensive to repair? Is the load sufficiently large and constant to insure the results anticipated.

For variable loads the engine cannot reach as high an efficiency as with a constant load; and economy must frequently be made secondary to securing enough capacity for sudden and momentary overloads.

Prof. Thurston gives the follow table as representing the best practice, as applied to the total number of expansions desirable, and best number for each cylinder:

	TOTAL.	SINGLE.	LIMIT OF PRESSURE
Single cylinder	5	5	50
Single cylinder	6	6	60
Compound	9	3	90
Triple	27	3	270
Quadruple	81	3	810
Quintuple	243	3	2430

This does not accord entirely with western practice, where 80 lbs. for single, 100 to 120 for compound, and 150 to 200 triple expansion, are

thought to be about correct. I have not, however, been able to find any data warranting these figures.

In fact the superior actual efficiency of the engine No. 7 over No. 1 in our table, may possibly be explained by the fact that the superior temperatures and pressures were entirely too low in the latter case.

The efficiency of pumping engines is measured in foot-pounds of work done by 100 pounds of coal burned. And in order to eliminate the question of the quality of the fuel and the efficiency of the boiler, an evaporation of ten to one is often assumed, so that the duty then becomes the number of foot-pounds of work done by the engine with 1,000 pounds of dry steam. In order to compare the efficiency of pumping engines with that of ordinary engines, I have deduced the following formula:

$$D = \frac{1980}{S} \text{ or, } S = \frac{1980}{D}$$

In which D is the duty as last defined above: and S the lbs. water evaporated per h. p. per hour. It is sufficiently accurate for ordinary purposes to call the figures 2,000, which greatly facilitates carrying the formula in ones mind.

The formula as given is not strictly accurate: as the duty is always net useful work, while steam efficiency is usually measured per indicated horse power. The former, in case of engine No. 1, in our table, was exactly ten per cent less than the latter. This loss is slightly greater than usual, however, on account of the necessarily complicated construction of the engine. It frequently falls to five per cent with ordinary engines of good construction.

THE RELATION OF RAILWAY SIGNALING TO TRAIN ACCIDENTS.

[By W. W. Salmon, Member Western Society of Engineers.]

(Read March 1, 1893.)

It has been said that there is no profession of modern times requiring the same exact and extended knowledge as engineering. In no particular branch of this profession is more required than in railroad engineering. In the location, construction and maintenance of railways the engineer is required to pass judgment upon all the manifold appliances used, from a nut lock to a cantilever bridge. With every problem involving the use of material or labor, in any degree, he is directly concerned, and it will be conceded that the railroad practice of to-day, with its numberless improvements over that of a few years ago, is chiefly of his creation.

We are all familiar to some degree with the thought that has been devoted to the finding of the proper relation which the sections of rails and car wheels should bear to each other ; the chemical composition of rails has commanded the attention of the best experts, and many a hard fought battle has been waged as to the proper and allowable percentage of carbon, sulphur, phosphorus, silicon and manganese ; their manipulation and physical treatment have been but little less widely discussed. All have read the titles of treatises innumerable on bridge designing ; many have wrestled with the weary waste of unfamiliar terms, of which each writer seems to have a separate and voluminous vocabulary: some have followed the writers through differentials and integrals to the derivation of a beam of required strength and then have multiplied by six to make sure of the result. The United States Government commanding the services of experts, has sent out, from time to time, elaborate reports upon the use of metal on railways as a substitute for wood. Engineering papers have devoted, in the aggregate, thousands of pages to the discussion of axles, trucks, couplings, drawbars, brakebeams, switches and the "deadly car stove." All of these articles have been written to the end that railways might be supplied with devices that would enable them to handle their traffic cheaper, more safely, or with greater dispatch ; nor does there seem to be the least abatement in the attention directed to these several classes of railway equipment. It seems eminently proper, moreover, that until each individual device is perfected such discussion should continue, for, while there is much confusion in all this babel of tongues, there is also much that points the way to better things. But, while all this is true, it is a matter deserving of consideration that there is a field fruitful for the inventive genius, and in the development of which the safety of persons and merchandise in transportation depends more, at this time, than upon all else combined. No scientific or other elaborate treatises have been written upon this subject, and, while, as a rule, the various railways require their engineers to assume charge of this work, most of the details are referred to assistants, while the chief frequently remains ignorant and indifferent as to the various devices, good and bad, that are in use. I refer to "signaling." That a necessity exists for it, and that it should receive the close attention of practical and scientific men, may be demonstrated by the examination of a statement published in the *Railroad Gazette* of February 3, 1893, giving in considerable detail a list of train accidents, their nature and causes, in the United States, during the year 1892.

This statement shows that there were, in all, 2,327 accidents to trains, resulting in injury to persons or property in that year. It is probable that a much larger number of accidents really occurred,

since, as was said to me a few days since by a railroad official, a great many accidents of which he knows never are reported. However, for a comparison of the several classes of accidents, this will answer the purpose. The loss of property is not stated, but it may be inferred from the fact that on a certain road—operating about 1,200 miles, and with a smaller percentage of accidents than the average, $120,000 are paid out annually for this class of insurance alone. In these 2,327 accidents 672 persons were killed and 2,407 seriously injured. Of the total number of accidents 425 are unexplained, leaving a balance of 1,902 of which the cause is given. Of this number, 191 were due to defects of road, such as broken rails, poor ties, broken or defective switches, frogs and bridges ; 206 to defects of equipment, such as broken wheels, axles, trucks, failure of couplings, drawbars or brake-beams ; 179 to malicious or accidental obstructions, such as landslides, washouts, snow or ice, and 100 to various breakages of rolling stock, boiler or cylinder explosions, burning cars from sparks or hot boxes, making a total of 676 train accidents due to all of the causes above enumerated. Such a record affords a most excellent reason for all the volumes that have been written and the devices that have been offered to improve the existing conditions.

There were, however, in the same time, 164 accidents due to negligence in operating, including such items as misplaced switches and open drawbridges; there were also 1,062 accidents due to collisions, so that, reduced to the same basis as those accidents already enumerated, there were 2,124 accidents to trains due to collisions : of this number 1,922 were due to misplaced switches, failures to properly signal and mistakes in giving or receiving orders. Thus, out of a gross total of 2,964 accidents to trains, for which the cause is given, 2,086, or a trifle over seventy per cent. were due to the inadequacy of the signaling employed.

It is not possible to state, without qualification, that all of these accidents would have been prevented by proper signaling, but it can be positively stated that all of them might, and most of them surely would have been. In support of this position, a fuller examination of the individual causes entering into these several disasters may be pertinent.

Collisions due to misplaced switches have occurred chiefly where switches were located on or near curves, or in foggy weather when it was impossible for the engineer to see the switch target at a sufficient distance to enable him to bring his train to a stop in time to prevent disaster. It will surely not be questioned that a good switch signal located at a proper distance in advance of the switch would in all cases give such timely warning as would enable the engineer to stop his train.

Failures to give signals are admirably treated in the following quotation from a signal catalogue recently published:

"The protection of a train which has unexpectedly come to a stop between stations, by the ordinary method of sending a man back along the track with a visual or audible signal, is safe only when carried out by men of the very best judgment. Both the flagman who is to give the signal and the engineman of the following train must never fail to practice the most extreme caution. Moreover safety is always contingent upon the flagman having sufficient time to get back to warn a following train. This renders necessary the maintenance of very strict discipline and the establishment of precise rules for the conduct of trainmen. These rules can never be made to cover all possible contingencies for the reason that absolute safety implies the adoption of a uniform speed for all trains. Every "flagging rule" constructed with a view to complete protection, provides that the flagman must protect his train not only when it has stopped at an unusual place, but when it is losing time. As trains run at a great variety of speeds and the exigencies of bad weather, unexpectedly heavy loads, defective engines and other contingencies that cannot be described with precision, are constantly arising, no rule can be laid down with the expectation of its being always clearly comprehended by brakemen: the result is, that after the most painstaking effort to lay down a rule which shall unerringly guide a brakeman in the performance of his duty, the superintendent must trust to the brakeman's judgment. While it is true that much of the loss of life from collision, resulting from ineffective flagging, has been caused by the most palpable negligence on the part of trainmen, and the sufferers are often plainly the victims of their own negligence, the fact remains that money losses from accidents of this kind constitute an important item: so that, aside from the consideration of humanity, which every superintendent feels regardless of fine distinctions as to whether the death of the brakeman or engineer was caused by his own fault or that of another, the mere financial question is one which all will admit to be a serious one."

Mistakes in giving and understanding orders is another source of numerous collisions. Nor can anyone, familiar with the manifold duties of the men who give and receive such orders, wonder at the casualties. A train dispatcher directing the movements of a great number of trains on a busy section of road, the operator, receiving or transmitting the same, handling tickets and busy with the numerous other details of station work, the conductor taking up tickets, directing shifting movements, handling car manifests; surely it would be a miracle if some one of these men should not commit some fatal error.

It cannot be expected that there will ever be any considerable decrease in the number of accidents occurring from these causes, through any improvement in the "personnel" of the trainmen and operators employed. The probabilities are that the 800,000 men in the employ of American railways to-day are quite as careful and intelligent as an equal number of men in similar positions will be at this time next year, or a decade from now. We must, therefore, look for something other than a mere system of train orders and hand-signals, and this something is a properly designed and operated system of fixed block signals.

It is outside the scope of this paper to define in detail what such a system should be, since this is written solely to place before the members of the Western Society, as briefly as may be, a statement of existing conditions, which, unfortunately, are not at all well understood by many engineers of excellent standing in the railway world, whose influence, if properly directed in placing before the managers of their systems the desirability of having a complete signal equipment, would early lead to a better state of things. Doubtless there are many whose names are enrolled as members of this society who have devoted months to the study of bridge designing and inspection, to the end that failures of bridges may be better provided against, where they have spent minutes in the consideration of signaling. When, however, it is known that for every train accident during the past year, owing to a bridge failure, there have been forty accidents due to defective signaling, the importance of the latter problem becomes evident.

Within a month an engineer of prominence stated to me that his road, which is not provided with block signals, has about as good a record for freedom from accidents as some which are signaled, and unfortunately for the effect that it may have upon men, who, like this one, have not made a thorough study of the subject, the worst accident which occurred in 1892 was on a road provided with block signals. In order to forestall the criticisms which would be provoked in the discussion of such a paper as this, owing to this fact, the following statement may not be out of place:

Quoting from the *Gazette* of February 3, 1893, "The worst accident in 1892 was the rear collision at Harrisburg, Pa., June 25th, in which twelve persons were killed. This was due mainly to the negligence of an engineman, but it was contributed to by a bad 'failure of block working,' and by many is regarded as due to that failure."

Owing to the prominence of the road on which this accident occurred and the advertising which its block system has received, such an accident is sufficient proof to many railroad men that block signaling is a failure. If, as is unfortunately true, a considerable number of

similar accidents occur under this system of block signaling, it certainly affords reasonable ground for the belief that this particular system is not perfect ; and, in truth, it is only an improvement over the hand and flag signals in so far as these have been superseded by the use of fixed signals, giving particular and well defined points at which they are to be looked for; and by shortening the distances between stations by the insertion of intermediate block towers, thus reducing the number of trains which it is necessary to pass into a block at one time, and by the substitution of regular block operators for the nondescript force pressed into service under the old system. In these three respects there is an advance over older methods, but it is, at the best, only a patching up of an old garment well enough fitted to the needs of the young railways of a generation ago, but by no means suited to the giants of to-day.

In this system, as in the older ones, exist all the elements of possible accidents from wrongly displayed clear signals, owing to the forgetfulness, carelessness, over-confidence and incompetency of operators. There is absolutely nothing to prevent the operator from clearing signals whenever he may think it proper to do so, and if his "book-keeping" be at fault, as it sometimes is, he may do so. At this writing, I notice in the *Gazette* of February 11th, that "George June," the operator at "H. B" block signal tower on the Pennsylvania road, who gave the clear signal which lead to the recent collision (January 19, 1893,) has been arrested on a charge of manslaughter and sent to prison in default of $10,000 bonds." It is not possible to state to what degree this operator was criminally negligent, or whether he was negligent at all, but it may not be amiss to inquire where we would find room for them, if all the railroad men who make mistakes are to be sent to prison. Convicting this and that employe for manslaughter will not prevent a recurrence of similar casualties. What is needed for the protection of railway property, employes and travelers alike is not so much the punishment of the man whose misfortune it has been to be the immediate cause of disaster, as the provision of well known and tried devices, the use of which would make it impossible for the operator to wrongly display a clear signal. In other words, it means the abandonment of old and dangerous methods of signaling for newer and safer ones, where, by automatic appliances, a train, upon entering a block section, sets the signal at the entrance of this section to danger and makes it impossible for the operator to again clear it, until the train shall have passed under the protection of the next succeeding signal, setting it to danger.

As an example of the simplicity and adaptability of such a system it may be noted that the New York Central and Hudson River Railroad has, within a year, installed about one hundred lock and block towers,

without a single accident. That two hundred signal operators, most of whom were entirely new at block tower work, should have been able to successfully and safely operate such an installation, speaks volumes for the merit of the system used. This is all the more striking when the former record of accidents on this road is remembered.

All, therefore, that need be stated as to the requirements of a signaling system, whether it be auto-manual, electro-pneumatic or automatic-electric, may be briefly stated as follows :

The cost of installing and maintaining the system should not be so great as to prevent its economical adoption and use by railroads. It should prevent the display of a clear signal falsely ; should not become so readily disordered when properly maintained, as to display any great number of danger signals unnecessarily, since any system which has this defect will ultimately fail to command the confidence and respect of enginemen and thus invite disaster by frequently requiring them to run against danger signals when no danger exists. Any signals which during cold weather stick or freeze at clear, with an open switch or train in the section, or which are so susceptible to change of temperature as to become unreliable, owing to the frequent and unnecessary display of danger signals, would of course not be considered as meeting the above requirements. The apparatus employed should be reliable and durable, and no railroad company buying, or signal company, selling, such apparatus should advocate the use of any instruments whose chief claim for consideration is that they are cheap. Where valuable property and human lives are the prices to be paid for failure, there should be no question as to which of two devices should be used when one is cheap and unreliable and the other expensive but trustworthy.

Before bringing to an end this paper, which has been prepared wholly for the purpose of directing the attention of the members of this society to a subject, the importance of which is but little understood, it may be interesting to quote an item of news relative to the view taken of signaling by a railway president of great sagacity, both as a financier and practical operating official : "The Boston News Bureau says that the Boston and Maine recently considered the question of reinsuring against accidents for which it has been paying about $120,000 per annum, but Mr. McCleod declared that the best insurance against accidents was modern railroad equipment, and that what the company was paying for accident insurance was far more than the interest at four per cent. upon the cost of block signaling the entire line, and that a block signal system would save lives as well as accidents. The result is that the Boston and Maine will not reinsure, but will immediately put in a block signal system."

When more railway managers take the same view of the matter that Mr. McCleod is quoted as having, and follow them up by equipping their roads with proper signaling plants, the dividends of certain accident insurance companies will decrease, while there will be a corresponding increase in those of railways, and there will be fewer accidents to chronicle with the harrowing details familiar to us all.

PROPOSED TUNNEL AT DULUTH, MINN.

Discussion of Various Plans for Proposed Tunnel at Duluth Minn., before the Civil Engineers' Society of St. Paul, Minn.

[March 13, 1893.]

Preliminary Note.—The *Engineering Record* of February 4, 1893, presents the prize tunnel plan and the report of Expert Artingstall, which will give an idea of dimensions and general requirements.

The plan was also shown in *Engineering News* of February 2.

After the award twelve competitors kindly loaned their plans and specifications for purpose of discussion.

President Wilson:—The meeting this evening, gentlemen, is for the discussion of the various plans for the Duluth tunnel, now before us, and I would suggest that we take up especially the questions of practicability and the conditions existing at the site of the proposed improvement, and consider each of the plans in rotation. As a basis for a comparison of cost, I have prepared a table giving the cost of different items which are common to all the plans, and the estimated total cost of the whole, as follows:—

NAME OF DESIGNER.	GENERAL DESCRIPTION OF PLAN OF CONSTRUCTION.	Estimated Cost.	Stone Masonry per cu. yd. 1st. Class.	Stone Masonry per cu. yd. Rubble,	Brick Work per 1,000.	Concrete per cu. yd.	Excavation per cu. yd.	Excavation per cu. yd. By Dredging.	Iron per ton.	Timber per 1,000 ft.	Granite Paving.
M. Toltz	Brick Tunnel, built in iron shell. Constructed by pneumatic process.	$559,000	—	$6.50	$20.00	$ 3.25	$1.25	—	$60.00	—	
C. A. Buckelew.	Submarine tunnel built of iron afloat and sunk by loading with ballast. Trench previously excavated...........	587,557	$10	—	—	10.00	—	20c.	Lump Sum. $327,591	—	
A. S. Danridge.	Brick tunnel, built in iron shell......	560,000	—	5.00	15.00	—	—	22c.	$32.50	$15.00	
E. D. Bolton.	Brick tunnel—all brick—constructed by pneumatic process....................	955,378	Granite. $25	Sand-stone Appr'ches. $8.00	Am. cem'nt $15.00 Port. cem't $18.00	8.00	Approaches, 50c.	Under canal. 2.50	—	—	
C. C. Conkling.	Concrete tunnel lined with brick, built in open trench......	796,400	—	7.50	18.00	5.00	All given at 30c. in estimate. 30c.	$1.00	—	—	$3.00
J. M. Shanley.	Concrete tunnel, entirely..................	655,800	15	—	—	7.00	35c.	60c.	—	30.00	3.50
Chas. F. Muller.	Brick tunnel, to be built in sections afloat, then sunk and strengthened by inside additional lining of brickwork.	949,000	—	—	12.50	5.00	—	25c.	—	20.00 to 28.00	
C. F. L. McQuistion.	Trench to be first dredged. then piles driven for foundation and caisson sunk on piles. The concrete bottom to be then put in and brick arches for tunnel	626,419	12	7.00	19.00	6.00	$1.50	—	44.00	15.00	
M. Wymand.	Trench to be sheet-piled and afterwards excavated inside of same. Tunnel to be built of cut stone masonry. Piles to be driven in trench for bracing. Sheet piling and piles driven by water-jet..............	691,200	12	5.00	—	5.00	—	By Pumping 12c.	—	23.00	
St. George Boswell.	Timber tunnel lined with 4 inches of brickwork. Trench to be dredged out and cribwork sunk in sections on pile foundations. Sections 200 to 300 ft. long.	623,000	10	—	12.00	4.50	20c. to 25c.	—	—	—	

Being obliged to withdraw for the present, I will ask Vice President Estabrook to take the chair.

PRESIDENT:—What is your wish, gentlemen? I hardly suppose we are prepared to discuss these plans from the tables President Wilson has just read.

MR. MUNSTER:—I would suggest that before commencing the discussion that we consider certain physical conditions prevailing at the site of the proposed tunnel. I understand that there are heavy waves; that there are storms on some 90 days in 365, or about one day in four. Mr. Stevens tells me that there is a steady current through the canal; not steady one way, but sometimes towards the lake; at other times reversed. Perhaps it will be well to establish those facts first.

PRESIDENT:—I think it would be well to realize what we have to contend with.

MR. TOLTZ:—If you will allow me, I will read from my paper of the other night. It will bring the matter to your memory again:—

"Starting from the northern shore of the lake, some 2,000 feet from Minnesota Point, the United States built a breakwater, which in 1872 had reached the length of 1,200 feet. It was formed of cribs thirty feet long, and was provided with a deck superstructure to a height of six feet above the water level. Although built in the most substantial manner of such structures on the lakes, it was wrecked by a storm which occurred on November 14, 1872. But little of it now remains, and it has been abandoned.

"The cause of this destructive action is to be readily found in the formation of the land on the northern shore of the lake in this vicinity. Rising to a height of about 700 feet above the level of the lake, it seems to direct easterly winds towards the location of the breakwater and the entrance of the canal, rolling the resulting seas, with accumulated force, in the same direction. It is easily conceivable that their force should prove almost irresistible by any structure less substantial than those built to withstand ocean storms."

The principal question which arises is, which is the safest as well as the cheapest method of construction? Here are many plans, and if I remember 23 were submitted. The Board of Public Works laid all plans aside contemplating the method of excavating by dredging or having an open ditch without any side sheeting, because the sand is so fine that it slides with a slope less than 4 to 1. This would make the trench from 450 to 550 feet wide and involve damages to the property on Minnesota Point to the amount of about a million or a million and a half of dollars. There are many houses along the line of the tunnel which would have to be removed. For this reason they decided to use a design where they keep to the width of the street,—80 feet or the width of St. Croix avenue.

Mr. Conkling's design is for an open trench, sheet piled, for three tunnels; one to be used for the railroads, one for street thoroughfare, and one for foot passengers. The base of these tunnels is 72 feet wide, and the danger of having a ditch 72 feet wide and over 50 feet deep is

apparent, especially in fine sand. There would be great difficulty in driving the sheeting he proposes to use; he does not describe the manner, whether in rows or in sections, or whether they should be 50 or 60 feet long. I think it would be difficult to drive the sheeting down and then dig out this trench; the sand is very fine, and is a kind of moving sand, so that it will bubble up from below.

MR. WOODMAN:—Does he make any floor? Ans.—He excavates with the water in.

MR. MUNSTER:—I would like to ask Mr. Keating as to the currents; he is probably well informed, as he was the city engineer of Duluth for some time.

MR. KEATING:—There is a very rapid current both ways. I think it is between three and four knots an hour.

MR. CAPPELEN:—I would state that it seems impossible to drive down sheet piling 72 feet apart and 60 feet long at this point; it is impracticable.

MR. ANNAN:—The estimate calls for $100,000 for bracing.

MR. CAPPELEN:—It would take Howe trusses for bracing every four feet in order to do it.

Q.—How deep is the channel of the canal, Mr. Keating?

MR. KEATING:—That channel was dredged out 13 feet some years ago; last year it was 32 feet. I know it is through very fine sand. I don't know how they are going to drive those piles.

MR. MUNSTER:—I think it would be well, also, to analyse a little the conditions that have to be met in the construction of a cofferdam of the size and depth required by Mr. Conkling's plan. We will suppose that he has succeeded in driving practically water-tight sheet-piling to the required depth, of about 65 feet (a rather difficult undertaking, I surmise). He will then have to brace this cofferdam against the water pressure as the pumping and the excavation proceeds. At the bottom of excavation this pressure will be about 3,450 pounds per square foot; and assuming that his struts across the 75-foot cofferdam will have an ultimate strength of about 2,000 pounds per square inch, it would require about 7 square inches of strut for each square foot of wall of sheet-piling, and if the struts are placed in sections about 10 feet apart, and we assume the struts to be 12×12 timbers, they should be placed about one foot apart at the bottom, the distance gradually increasing to about 3 feet at the point where the excavation commences. To transfer the pressure of these walls to these struts would require a solid wall of horizontal timbers from 13 inches thick at the bottom to about 9 inches at the bottom of the canal.

I give these figures not as a design for a cofferdam, but merely that we may realize better the forces to contend with.

Another point to be considered is how to pump the water out of this

cofferdam. If the builders, by some means known to themselves, have succeeded in constructing the sheeting, and the bracing, completed the excavation, and put in place the five feet of concrete that the plan shows; if the cofferdam was then pumped out, it appears to me that in that material we would have a pressure acting upward on this concrete bottom nearly equal to the hydraulic pressure, and it would require about 25 feet thickness of concrete to counteract this pressure by its weight.

Mr. Cappelen:—I will guarantee that he will have to drive three rows of piling. They had all the trouble they wanted in the Chicago river in an impervious clay; the piling broke off like pipe stems.

President:—We have a flowing material with pressure on either side, and something has got to come. It seems to me it is a mistake when you attempt to pump out the sand; the piles and the whole thing will come up the same as it does in the mines.

Mr. Keating:—I think that the difficulty would be that the sand and water could come up below the sheet-piling. I think they tested the material down some 117 feet and that 88 feet was sand. The great difficulty would be that it would come up from below. I know that in 32 feet of water we had great difficulty in handling it; if we had not had rock below I don't know what the result would have been.

Mr. Toltz:—In my opinion, the mode of construction of Mr. Conkling's tunnel is not just an ideal one. He states that he builds up his sidewalls with brick and concrete and that the concrete should be well rammed. He further builds the 12-foot brick arch on false work and then puts the concrete on top of the arch: as the concrete on top should be rammed as well as in the other place, this ramming will destroy the bond of the brick arch.

Mr. Cappelen:—Best to build your concrete first and then your brick arch afterward.

President:—This condemnation of this plan applies equally to all open cofferdam work. Some of them propose to restrain the sand with sheet-piling, though most of them dredge out and then drive the piling. It will be very difficult to maintain the piling.

Mr. Cappelen:—You drive your outside sheeting, then to overcome the pressure you can put in the intermediate walls and brace between them. Some such idea must have been contemplated, although the plans do not indicate it.

Mr. Toltz:—Mr. Shanley's plan is similar to that of Mr. Conkling's. The expert rejected it because the arches were not strong enough. Mr. Wymand's plan is about the same as Mr. Conkling's, except one tunnel is excavated at a time. The trenches are 24 feet wide, and the sheet-piling which he drives in sections of about 24 ft. in length, are well braced with 12×12 inch timber, crosswise. After one tunnel is

built, the trench is to be filled up and excavation of the other then commenced, leaving the sheet-piling next to the second tunnel in the old trench, only on one side new sheet-piling has to be provided for.

PRESIDENT:—Is it practicable to sink that narrow trench and make it dry so you can proceed with the work?

MR. WILGUS:—He can not get the water pumped out if he undertakes to pump out after driving the second set of cofferdams. It is impracticable without having some method of keeping the water from coming up from the bottom.

MR. TOLTZ:—I have driven tunnels and excavated ditches here in the city to a depth of 40 feet in sand which contained a good deal of water, one at Mt. Airy street. In the open trenches we could keep our sheeting in good shape; the sheeting was 16 feet long and we used three sets. Water was boiling up but we drove the sheeting below the subgrade and got along nicely. I think it can be done in sections by taking precaution and going down slowly on either side of the canal. The sheet-piling must, of course, be driven far below the bottom of the tunnel or subgrade, then, by putting in a certain amount of concrete the ditch would be prepared in such manner that the water could be pumped out. Mr. Wymand uses sand pumps, which in this case are practicable. The sheeting could not be driven in one row, or in one length of 50 or 60 feet, it is impossible. I have driven pipes in wells for water supply in Germany and I know how hard it is to drive them, even with water-jets. Now, in regard to the excavation at 12 cents per cubic yard, as mentioned in his estimate, I am convinced that it can not be excavated in that manner for less than 75 to 90 cents.

MR. CAPPELEN:—The question is, can you get the piling down? The situation indicates at least 60 feet of piling and I claim that it is absolutely impossible, it can not be done. If he had shown several rows of piling and then proposed pumping out and driving piling I think it could be done.

MR. KEATING:—I think you will find the water will run through the sand quite as rapidly as if it were water alone. To obtain wells on the Point they simply drive a tube down in the sand and they never can pump one of those wells out. It is an exceedingly fine sand.

MR. TOLTZ:—I would call your attention to Mr. Buckelew's plan of an iron tunnel. In case they would have allowed an open trench this would have been the right plan. Here is the model of the tunnel. This is to be sunk down in sections after it is floated into place and the boxes filled with concrete or ballast. At each end of the section is a bulkhead, which prevents the water from entering the tunnel proper. After one section is in position the second is sunk, properly adjusted and connected with bolts. It will have to be a good fit and for this

purpose rubber packing is provided at the joints. I consider this a very good plan.

Mr. Munster:--I think the Board of Public Works was somewhat in fault in not acquainting the competitors with the rapid current in the canal, and the exposure to heavy waves. If these facts had been known, none of the designers would have dreamed of maintaining an open trench as part of their plan.

President:—I think this and all similar plans are condemned because they contemplate an open trench.

Mr. Munster:—I do not think that would condemn this plan; it is merely a detail which could be changed by using protective sheet-piling, the plan ought to be feasible. Speaking in a general way of an iron tunnel, I think that it is perfectly practicable.

President:—How would you preserve your trench while you are lowering your iron sections?

Mr. Munster:—I am not prepared to give details; it merely occurred to me that this could be done by using some kind of protection to prevent the sides from caving in and the current from filling the trench with sand.

Mr. Cappelen:—It seems to me that the Board had no right to throw out any scheme for dredging in the channel proper. It could be done in the winter when the lake is frozen over and you would have no wave action.

Mr. Munster:—We have the sand and the rapid current which would be liable to fill it up in a very short time.

Mr. Cappelen:—At the beginning of your trench you could drive some light sheet piling.

President:—You think it would be practical to dig an open trench? I think the approaches are open to the influence of the storms and the nature of the channel is also against it.

Mr. Munster:—Wouldn't it be perfectly feasible to complete this part in the winter time?

Mr. Toltz:—If the excavation was done with the dredge, the width of the trench would nearly equal the width of the point, which is about 1,000 feet. We must consider that in dredging the slopes stand 4 to 1.

President:—The next design is that of Mr. Dandridge—open cut. Same principle as Mr. Buckelew's.

Mr. Toltz:—His plan certainly shows a slope of 1 to 1. That is impossible. Neither can we construct those round ditches in this material. This tunnel consists of an iron shell with brick lining. He uses some expansion joints which are very complicated.

President:—The next is the pneumatic—Mr. Bolton's plan.

Mr. Munster:—As that and Mr. Toltz's plans are of the same gen-

eral principle, I would suggest that they be considered together.

Mr Toltz read at length from his specifications.

Mr. MUNSTER:—One question. Mr. Toltz, is there a shield used in front? Ans. None at all.

MR. MUNSTER:—The distance of the pilot plate from the top of the arch would be about six feet. The top of the arch under the canal would be just beneath the concrete you have placed in the bottom of the canal. That sand would be filled with water. I think there the trouble would commence, under the canal. If it was clay it would be different, but with that flowing sand it could not be done.

MR. TOLTZ:—Mr. Artingstall says it could have been done if the top and the concrete wall was heavier so that it could stand the pressure of the water on top. He said further that this tunnel would twist even with the bracing. His reason for this objection I am at a loss to know.

MR. MUNSTER:—I think the trouble will be under the canal—the sand will cave in. On account of the small amount of material on top of the tunnel I think it would be more practicable if you could fill the canal with sand.

MR. WILGUS:—I took the trouble to look up the records of the St. Clair tunnel. It twisted 20 degrees in one direction and 30 in the other, or a total of 50 degrees.

MR MUNSTER:—Only difficulty as far as I can see is that I have mentioned. The use of a shield might obviate that. I think with material like this sand the air pressure wouldn't hold it in place, especially under the canal. I think you will have the sand caving in underneath the concrete, even if you get your concrete in all right.

In regard to Mr. Howe's plan, I would like to call your attention to one objection. He has his foundation on the gravel, without any continuous concrete foundation so the water would have free access to the tunnel after it was built.

MR. ANNAN:—There have been objections offered this evening to both the open trench and pneumatic process, though either would seem to be economical compared with the Sooy-Smith plan which called for an expenditure of a million or more, as I understand it. The open trench bug-bears are the almost solid bracing required, and the sieve-like bottom of the trench; while the compressed air seems likely to fail under the canal on account of the thinness and saturation of the material near the top. It occurs to me that the two methods might be combined. Under the canal the sidewalls might be advanced in independent iron shells and a shallow tunnel excavated between in which to lay the base of the work: the iron plates in both cases to be temporary. Cofferdams might then be put down and the arch built in open trench.

PRESIDENT:—Perhaps Mr. Keating can describe the former tunnel proposed there?

MR. KEATING:—The former tunnel I can hardly describe. It can be found in the 1890 report of Mr. Sooy-Smith. He used the pneumatic process and freezing.

PRESIDENT:—That is feasible, except from a money point of view.

MR. WILSON:—In this competition there is one point that impresses me especially, which is, that owing to a failure to take up the problem in the same way a large number of the plans (those to be constructed in a dredged trench) were not considered. This seems hardly fair, as the invitations for plans provided that right-of-way and land damages were not to be considered in the estimate of cost, and shows the difficulty of specifying conditions for a competition of this kind and the dissatisfaction that will always be felt with the result.

Of the plans submitted for construction in open trench none of the designers appear to have considered the difficulty of properly supporting and bracing the sides while the work is being constructed, nor do they take sufficiently into account the water pressure from below and provide for a water-tight bottom.

The feasible method of construction, it appears to me, is the one proposed by Gen. Wm. Sooy-Smith, to construct the tunnel in sections on caissons to be sunk by pneumatic process, and his estimate of cost, $996,440, for one tunnel for street purposes and one for railway use, appears to be comparatively near what the actual cost would be. The plan and estimate of Mr. E. D. Bolton seems also to be a good approximation.

It is to be noted that the design of Mr. Toltz, or Mr. Bolton's, and several of the others, could be constructed in this manner, i. e., in sections on open caissons, with a working chamber beneath, to be operated by the pneumatic process exactly as bridge piers are put down, and with more certain results than by the use of tunnel methods.

MR. WOODMAN:—If the cost of executing one of these plans should not appear to be excessive in comparison to the benefits to be derived from the completed work, no doubt a tunnel will be built. But I doubt the economy of the undertaking, the commercial value of the improvement. The Bay of Superior is very shallow for a long distance from Minnesota Point. Therefore in order to make docks and wharves along the point, an enormous amount of piling and dredging will have to be done. In course of time the demands of commerce may require the necessary outlay for these docks, but they are not needed now, nor in the near future.

My observation of the canal, and of the existing industrial and commercial conditions of the city, has led me to think that all probable needs for a long time to come can be met in a simpler and much

cheaper manner, that will justify itself on financial grounds and leave the problem and the burden of bridging or tunneling the canal to the next generation. The suggestion is, to use a steam ferry in summer and a temporary bridge in winter. I would cut a slip on each side of the canal, at right angles to it, of sufficient depth to take in the full length of a powerful ferry that should be adapted to transfer railway cars, street cars and passengers. The canal would thus be left entirely free when the ferry was in either slip. The ferry would be thrown across in a very few minutes, and in all but the worst storms undoubtedly could be warped from slip to slip. During the months when navigation is closed the ferry would be laid up in the harbor, and a temporary pile bridge would take its place.

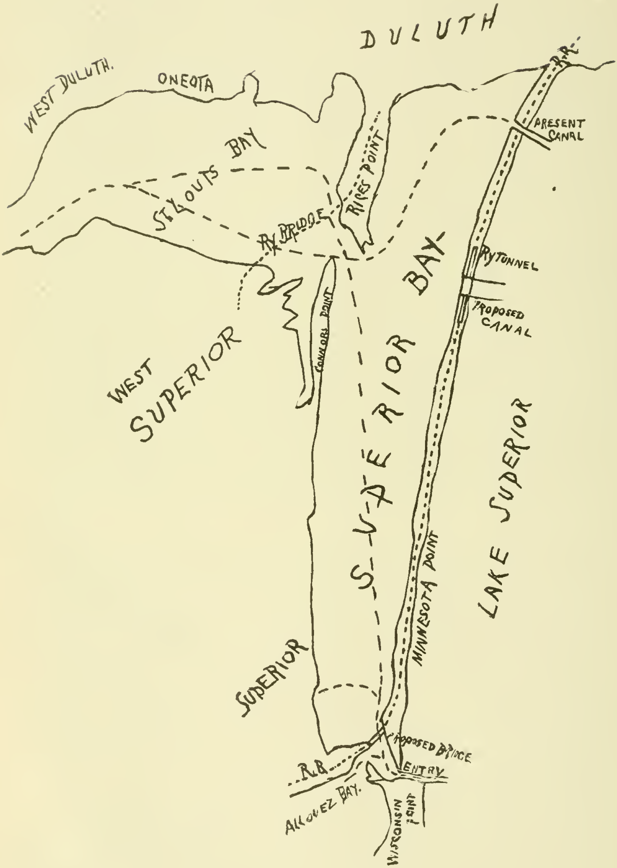
Mr. Keating:—There is just this about the dockage on the Duluth side of the harbor: I understand that the greater part of it is already owned by the railroads, and it is necessary to have ground for additional facilities, and that is the object in trying to utilize Minnesota Point. It has been proposed to run a trestle bridge as the cheapest way to get to the Point, from Fifth avenue west to strike Minnesota Point 800 or 900 feet south of the canal. That was proposed as one of the cheapest and most feasible plans. It was feared that the government might object to that also. The people of Duluth have made up their minds that it is necessary to get across the canal.

Mr. Stevens :—Without undertaking to discuss the details of any of the plans proposed for the tunnel under the Duluth Canal, I wish to call attention to some of the more general conditions incident to the work.

The foundation must be to exceed 50 ft. below the surface of the water ; the material is a clean, fine sand; the rapid and reversing current through the canal positively forbids the success of any plan having in view the dredging of an open cut across the canal with the expectation of sinking any tunnel construction into it. The moving sand would fill the cross-cut as fast as dredged. The top of any tunnel construction necessarily forms the bottom of the canal, or a great increase of approach grades must be made. The shield process of tunnel driving is, therefore, barred, for the top of the shield would be in the water. For the same reasons the pneumatic and freezing systems are of very difficult and, perhaps, impracticable application.

The method remaining is by the use of coffer dams. This has been discussed. I think it the only practicable way, but it has been shown to be a very difficult and very expensive one. I do not think any of the estimates made for it nearly provide for the necessary expense.

If you will call to mind the outlines of the bays of Superior and St. Louis, and the present location of the docks, and, further, the probability of the great extension of these docks in the Bay of St.



SKETCH MAP USED BY MR. STEVENS.

Louis, I think you will agree with me that the location of the present canal is a mistake. A portion of the harbor of Duluth is greatly damaged by it; ships lying where most easily accessible from the city, are roughly used by the waves rolling through the canal, made by a north or northeast storm. Ships bound for St. Louis Bay have to make a circuitous course to reach its entrance. This harbor is of great importance and will always be one of the great shippers of the lakes. For its improvement, a comprehensive plan for its most complete ultimate improvement should be adopted. This plan must include the improvement of Minnesota Point and must have the best railway terminals. A belt railway offers for a transportation center the best transfer facilities, and must in this case cross the ship exit to the lake on Minnesota Point. To make a crossing under the present canal is a hazardous and very expensive undertaking, and when done it is not rightly located.

I would advise :

1st. The building of a railway tunnel on Minnesota Point opposite the mouth of St. Louis Bay, at a depth great enough for the excavation of a ship canal over it. To build this tunnel before the digging of the canal would admit of methods of work greatly cheapening its construction and would avoid the hazard of a disaster.

2d. Following the building of the tunnel, dredge a new canal over it.

3d. When this new canal is ready for the use of ships fill the present canal and complete the belt railway along Minnesota Point, crossing from its extremity to Left Hand Point by a bridge.

This done, the harbor at the head of the lakes, with its railway transfer reaching all points, and its great mileage of land-locked water-front will not be surpassed in the world. The present entry should be left for the use of Allouez Bay, other shipping passing in and out the new canal.

NEW STADIA CHARTS.

By Edward P. Adams, Member Boston Society of Civil Engineers.

[Described November 18, 1891.]

Two extra horizontal lines, called "stadia wires," and a "telemeter rod" enable us to measure direct distances between the transit and the rod. With the addition of a vertical circle we can obtain both horizontal distance and vertical height between points.

The use of the stadia in measuring horizontal distance only is rapid; but when the telescope of the surveying instrument is not level, the use of stadia lines in obtaining both height and distance of the point where the rod is held, is slow work, even with the use of tables, on account

of the calculation or interpolation required for close results.

To increase the rapidity of getting both distance and height in my own surveys with the plane-table, I have made two "stadia charts" which are here presented. (Fig. 1, A, and Fig. 2, B). For convenience

Sketch of Stadia Chart A.

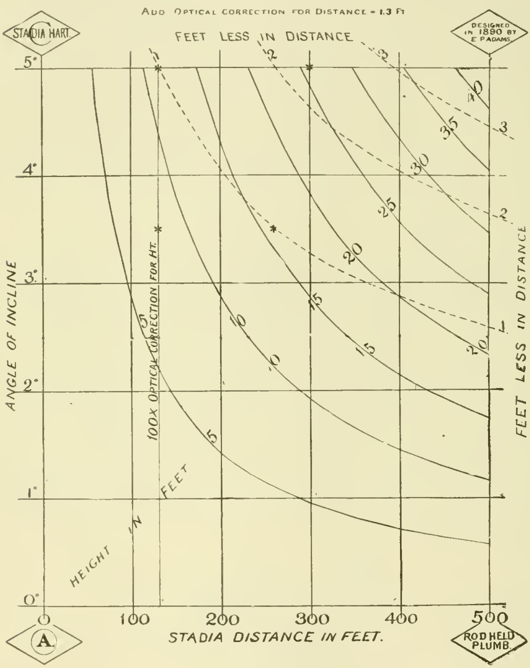


Fig. 1.

This shows fifteen per cent. of the lines.
A (*) indicates a point referred to in examples following description.

each was made of such a size that once folded it would be no larger than a field note book. The stadia distance and the angle of incline (*i. e.*, of elevation or depression from the level) were made the ordinate and abscissa of each point calculated for the charts. Curved lines of equal height), and another set of curved lines of equal "distance less

than the stadia reading" were drawn for every foot. The advantage of curved lines instead of straight ones is that they are equally distant horizontally, and for heights they are nearly equally distant vertically; and points between lines can be more accurately read, in conse-

SKETCH OF STADIA CHART B.

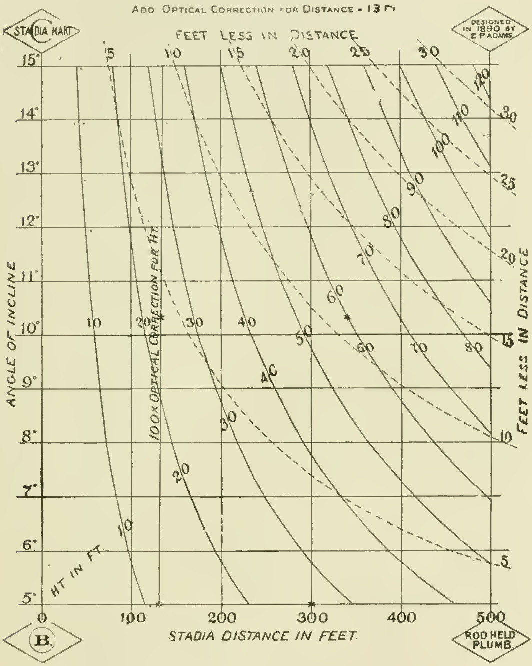


Fig. 2.

This shows thirteen per cent. of the lines.
A (*) indicates a point referred to in examples following description.

quence, than they could be in a chart made of straight lines only.

Calculations for Location of Lines. These curved lines of the charts were drawn through points, whose location was obtained by calculation in the following manner:

Let A in Fig. 3 be the axis of telescope of the transit, or alidade of

plane-table; B — the point at which the stadia reading begins, is in front of the object glass (G) its focal length (FG); F — the position of

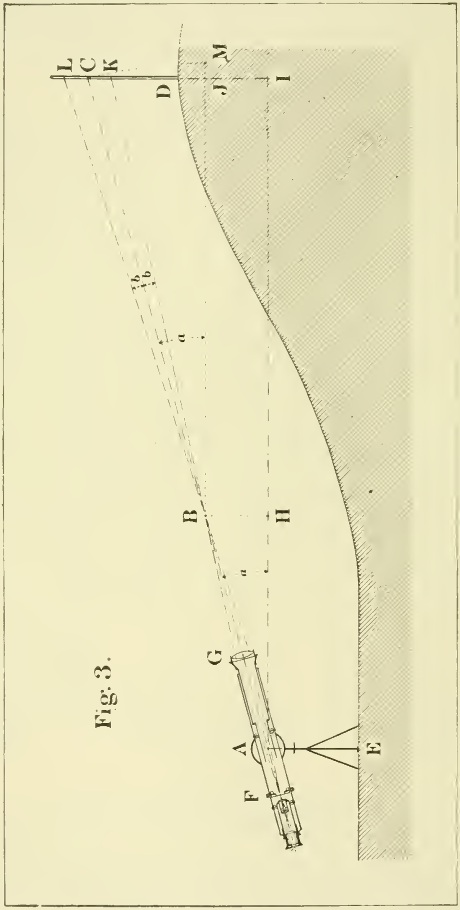


Fig. 3.

the stadia wires in the telescope; D — the point whose distance and height are to be determined, where the leveling rod is held plumb;

C — the point on rod sighted at; a — the "angle of incline"; b — angle of each stadia wire from center wire.

Then $CJ = BC \sin a$. $BJ = BC \cos a$.

But the rod is held plumb, not perpendicular to the line of sight, BC.

Therefore $KL = BJ \tan (a + b) — BJ \tan (a — b)$.

$$BJ = \frac{KL}{\tan (a + b) - \tan (a - b)}.$$

For the usual stadia ratio of 1 to 100,

$$BJ = \frac{KL}{\tan (a + 0^\circ 17' 11.32'') - \tan (a - 0^\circ 17' 11.32'')}.$$

AI, the distance required, $= AH + BJ$.

The "optical correction for distance," $AH = AB \cos a$.

$JM \times (100 \times KL) — BJ$, called "feet less in distance," is plotted on the chart; also CJ called "height in feet."

ID, the difference of heights required, $= BH + CJ — CD$.

The "optical correction for height," $BH = AB \sin a$. As $BG = FG$, $AB = FG + AG$. These should be measured for each instrument.

Angles of incline from 0° to 5° are on chart A, which is graduated to every 5′; and from 5° to 15° on chart B, which is graduated to every 10′. Distances extend to 500 ft., which is as far as the stadia can be depended upon to an unit, in reading distances. Both charts are graduated to every 10 ft. in stadia distance, to single feet in height, and to single feet in correction of distance, called "feet less in distance."

I have used photographs from the original charts, so that they would not be blurred by dampness, and could be duplicated.

As the constant, AB, varies in different instruments, the line in the charts marked "100 × optical correction for height" is drawn in red ink on the photograph; also AH, marked "optical correction for distance."

Method of Using. In the use of the new stadia charts, the following is the method to find the height and the distance of a point where the leveling rod is held plumb, the height of the instrument being known:

Set lower wire on the lowest foot mark visible; read the other two wires and the angle of elevation or depression from level.

With the angle read, and the distance shown by difference of lower and upper readings, as ordinate and abscissa on the proper chart, note the reading for "height" of their point of intersection, by means of

the figures along diagonal of chart. Then by means of same figures, note one-hundredth of reading of the point where line for angle of incline intersects the line marked "100 × optical correction for height." Add both "height" and "optical correction" to the height of instrument, if the point sighted at is above the level; subtract them if below. From this subtract height from line of sight to base of rod. The result is the elevation of base of rod above datum.

For the horizontal distance, (*AI*, Fig. 3.) note the reading at top or right side of chart, marked "feet less in distance" of point of intersection of ordinate for "angle of incline," and abscissa for distance, in the same way as above described for height. Subtract this distance from stadia distance read, and add "optical correction for distance" given in note at top of chart.

Examples. At a survey station, suppose 32.2 ft. is the height of instrument, whose "optical correction for distance" is 1.3 ft. (*AB*, Fig. 3).

1. Readings on rod, 3.00, 4.30 and 5.60; therefore stadia reading is 260 ft. Angle of depression, 3° 30′. (Use chart A).

Elevation above Datum.		Horizontal Distance.
32.2 ft.	. . Height of instrument.	
— 4.3 "	. (center wire), reading on rod, (stadia), .	260.0 ft.
— 15.9 "	. difference for angle and stadia distance, .	— 1.0 "
— .1 "	. . . Optical correction, ...	+ 1.3 "
11.9 "	. . . . . Result, ...	260.3 "

2. Readings on rod, 2.00, 3.50 and 5.00; therefore stadia reading is 300 ft. Angle of elevation, 5° 00′. (Use A or B).

Elevation above datum = 32.2 — 3.5 + 26.05 + .05 = 54.8 ft.

Horizontal distance = 300.0 — 2.3 + 1.3 = 299.0 ft.

3. Readings on rod, 1.00, 2.70 and 4.40; therefore stadia reading is 340 ft. Angle of elevation, 10° 20′. (Use chart B).

Elevation above datum = 32.2 — 2.7 + 60.0 + 0.2 = 89.7 ft.

Horizontal distance = 340.0 — 11.0 + 1.3 = 330.3 ft.

Notes. For distances between 0 and 50 ft., use 10 times the distance, and divide results by 10, in getting difference in height and distance (but not for optical correction). This will give the elevation to hundredths of a foot. For distances between 50 and 100 ft., divide distance by 0.2 and multiply results by 0.2.

Later and nicer calculations have shown that the heights in the upper third of chart B are about 0.2 of a foot too small.

The charts are marked "feet," but can be used for meters, if the "optical corrections," *AH* and the *AB* line, are according to the metric unit.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

THE CIVIL ENGINEERS' CLUB OF CLEVELAND.

MAY 9, 1893. Meeting called to order at 8 P. M. by the President. 30 members and visitors present.

The record of meeting April 11th., was read and approved.

A verbal report was received from the Local Committee on Columbian Exposition by Messrs. C. M. Barber, Chairman, and W. H. Searles, Secretary. The committee was enlarged by the following: Messrs. W. J. Blunt, Jas. Ritchie, E. P. Roberts, H. C. Thompson, F. H. Neff. Ludwig Herman, A. A. Honsberg and F. A. Coburn.

Mr. W. L. Cowles was appointed by the President as an Alternate Member General Committee of Engineering Societies, Columbian Exposition.

Mr. Porter presented a report from the Committee on new quarters to the effect that the needs of the Club were being considered in connection with the prospective new building for Case Library.

Mr. Cully introduced the following resolution:

"*Resolved* that we, the Civil Engineers' Club of Cleveland, Ohio, adopt the Ohio legal Standard Time and that hereafter the Secretary shall designate "Standard Time" in the call for meetings of the Club."

On motion of Mr. Searles it was referred to the Executive Board for action.

Mr. C. W. Hopkinson then read a paper on "The Proper Attitude Engineers and Architects should assume in attending the World's Fair." The paper was discussed by Messrs. Benjamin, Searles, Herman, Hopkinson, Coburn, Osborn and Palmer.

Adjourned. FRANK C. OSBORN, Secretary.

ENGINEERS' CLUB OF ST. LOUIS.

381ST., MEETING APRIL 19, 1893. The club met at 8 p. m., at the club rooms, President Moore in the chair, and twenty-two members and two visitors present.

The minutes of the 380th meeting were read and approved.

Prof. Johnson reported for the entertainment committee, and said the question of finances had been brought up and that the views of the club were desired.

Upon motion it was decided that a finance committee of three be appointed to solicit subscriptions. The President appointed Messrs. Meier, Ayer and Johnson.

Capt. Carl F. Palfrey then gave the paper of the evening on "Three Reconnaissance Maps in the Latter Part of the Last Century, as Compared with the Maps of the Mississippi River Commission." The paper was an interesting discussion of the changes in the river for the last century. The old maps, while containing some errors, were, on the whole, remarkably accurate.

Discussion followed by Messrs. Ferguson, Sedden, Blaisdell, Baier, Johnson, Moore and Ockerson.

On motion a vote of thanks was given Capt. Palfrey for his interesting and valuable paper.

Adjourned. ARTHUR THACHER, Secretary.

382ND., MEETING MAY 3, 1893. The club met at 8 p. m. at the club rooms, President Moore in the chair, and thirty-one members and two visitors present.

The minutes of the 381st meeting were read and approved.

The Executive Committee reported that at their 144th meeting the resignation of E. A. Engler was received, and the Committee on Local Data had been authorized to proceed with the printing of the book on local data.

The Montana Society of Civil Engineers sent word that they had adopted an amendment permitting an interchange of members with the societies of the association.

Mr. N. W. Eayrs presented the paper of the evening on "Corroded Girders in the Bridge Approach, illustrating a peculiar condition of the strains in the Webs of Plate Girders." The web in a number of the girders had been corroded and eaten away, leaving a number of large holes in the web. The girders were erected nearly twenty years ago. The destruction of the web was caused by the smoke and heat of the engines. In painting the girders a charcoal and litharge paint was found to be the best, owing to its remaining soft in spite of the heat.

Discussion followed by Messrs. Wheeler, Hermann, Moore, Kinealy, Sedden, Johnson, Ockerson, Condron, Baier, Ferguson, Bruner and Colby.

Prof. Johnson described a new apparatus for testing the girders in bridges.

For the next meeting, May 17, a paper by Mr. E. A. Hermann on "High Speeds on Railroads" was announced.

Adjourned. ARTHUR THACHER, Secretary.

383RD., MEETING MAY 17, 1893. The club met at 8 p. m. at the club rooms, President Moore in the chair, and twenty members and two visitors present.

The minutes of the 382nd, meeting were read and approved.

A letter from Mr. Corthell was read giving a description of the route laid out for the French engineers on their visit to this country.

Mr. E. A. Hermann then read the paper of the evening on "High Speeds on Railroads."

"The idea of high speed has risen from an average speed of 12 miles per hour on the primitive railroad to 50 miles on the best railroads of to-day, and now still higher speeds of 80 to 100 miles per hour are demanded. This could readily be accomplished if it were a question of motive power only. Either the steam locomotive or the electric motor could draw light trains at that speed. The comparative perfection of the motive power, however, is not equalled by that of the roadways and the facilities for preventing delays by interferences from freight and other slower trains. A railroad on which it would be safe to run trains at such high speeds would require four tracks to separate the fast trains from the slow ones; the cost of such a road would be so much greater than the cost of any existing road that its construction in the near future is very doubtful.

"It is more practicable to aim at a sufficient improvement of the existing railroads to permit the attainment of long sustained, moderately high average speeds. High speeds of 70 to 80 miles per hour are attained in regular daily service, but these speeds extend over short distances only on account of heavy grades, delays from other trains, etc. Where the railroads are improved sufficiently to permit a more uniform moderately high aveage speed such as could then be easily maintained, the running

time between terminal stations will be greatly reduced. All the first-class railroads are being gradually improved, and with these improvements will come higher speeds; they will be developed gradually in the future as they have been in the past, as the gradual improvement of the roadway makes such high speeds safe and profitable."

Discussion followed by Messrs. Ferguson, Wheeler, Sedden, Johnson, Kinealy, Moore, Bryan, Russell, Flad, Crow and Bouton.

For the next meeting a paper by Prof. Howe on the Hinged Suspension Bridge was announced.

Adjourned. ARTHUR THACHER, Secretary.

BOSTON SOCIETY OF CIVIL ENGINEERS.

APRIL 19, 1893. A regular meeting of the Society was held at its rooms, 36 Bromfield street, Boston at 7:45 p. m. President John R. Freeman in the chair. 72 members and 30 visitors present.

The record of the last meeting was read and approved.

Messrs. George F. Hardy and Francis H. Kendall were elected to membership.

The Secretary reported for the Board of Government the appointment of the following committees:—

On Weights and Measures. A. F. Burton, Lawrence Bradford and A. C. Walworth.

On Excursions. F. V. Fuller, F. I. Winslow, C. T. Main, H. C. Keith, and A. W. Locke.

On National Public Works. W. E. McClintock, L. F. Rice and Sidney Smith.

On the Library. H. F. Bryant, S. E. Tinkham, H. D. Woods, A. G. Robbins and L. F. Cutter.

On Permanent Headquarters. Thomas Doane, E. C. Clarke, E. W. Howe, Desmond FitzGerald and J. T. Boyd.

A communication was read from the Secretary of the General Committee of Engineering Societies inviting the Society to furnish a list of engineering works in and around Boston which would be open to the inspection of engineers visiting this country during the coming year. The communication was received and placed on file.

Mr. George S. Morison of Chicago was then introduced and addressed the Society on Bridges across Western Rivers. Mr. Morison described quite fully the difficulties encountered in securing foundations for bridges in the Ohio, Missouri and Mississippi rivers and spoke of the peculiar characteristics of each of these rivers. He then gave in detail an account of the more important bridges built by him, notably those at Plattsmouth, Bismarck and Memphis. At the close of the address a number of lantern views were shown of the bridges described by Mr. Morison.

A discussion followed upon various points in bridge building in which Prof. W. H. Burr, of Harvard College and Messrs. Worcester, Howland, Manley and President Freeman took part.

Adjourned. S. E. TINKHAM, Secretary.

ENGINEERS' CLUB OF KANSAS CITY.

MAY 15, 1893. A regular meeting of the Club was held in the Coates House Club Room, on Monday May 15, the President in the chair. Mr. S. A. Mitchell, Asst. City Engr., read a paper on "Sewage Disposal;" the paper was discussed by Messrs. Gunn, Mason, Donnelly, Keefer, Sickels Gillham and Whitney.

Resolutions upon the death of Mr. John E. Thomes were adopted after which the meeting adjourned.

WATERMAN STONE, Secretary.

JUNE 12TH., 1893. Regular meeting of the Engineer's Club of Kansas City was held at the Coates House Club room on Monday, June 12, 1893; eighteen members and visitors being present.

The President called the attention of the Club to the condition of the West Bluff and spoke of the desirability of beautifying the same, stating it as his opinion that there were no insurmountable difficulties in the way of this improvement. Major Gunn and Messrs. Mitchell and Mason were of the same opinion.

The paper of the evening, "The Problems to be solved in the treatment of Hyde Park Sewage" was then read by Mr. F. B. Tuttle.

The paper was discussed by Messrs. Gillham, Farnsworth, Thompson, Mitchell, Mason and Gunn.

Adjourned. WATERMAN STONE, Secretary.

MONTANA SOCIETY OF CIVIL ENGINEERS.

MAY 20TH., 1893. An adjourned monthly meeting of the Montana Society of Civil Engineers was held at the office of Messrs. Sizer & Keerl, in the Atlas Building on Saturday evening, May 20, 1893, at 8:00 o'clock.

Present: Messrs. Haven, Foss, Herron, Hovey, Cumming, Wheeler and two visitors.

The meeting was called to order with President Haven in the chair.

Minutes of the last meeting were read and approved.

An application for membership was received from Mr. M. E. Reed, and on motion of Mr. Herron the same was referred to the Board of Trustees. The application of H. C. Relf, for membership in the Society was favorably reported on by the Trustees and the Secretary was instructed to send out letter-ballots.

Letters were read by the Secretary from various mines and smelting works throughout the State in response to a request from him that foreign engineers visiting the State during the coming summer be permitted to inspect their works—also the list of important engineering works sent by the Secretary to the General Committee of Engineering Societies, Columbian Exposition.

Albert Moog was duly elected to membership in the Society.

A report was received from the Committee appointed at the annual meeting to draft a bill regulating the compensation of County Surveyors submitting a copy of a proposed bill, and on motion of Mr. Herron the same was ordered filed.

The Secretary was instructed to procure for the library of the Society the volume entitled "The Mineral Industry" published by the *Engineering & Mining Journal*.

Extracts were read by the President from a book entitled "Triangular Surveys from Single Stations," by Augustus Knudsen, also a review of the work by Mr. E. H. Beckler and discussion followed.

No further business offering the Society thereupon adjourned.

G. O. FOSS, Secretary.

ASSOCIATION OF ENGINEERING SOCIETIES.

ORGANIZED 1881.

Vol. XII. June, 1893. No. 6.

THE PROPOSED DEEP WATERWAY FROM BUFFALO TO NEW YORK CITY, AND SOME FACTS ABOUT THE SUEZ CANAL AND THE NUMEROUS PROJECTED AMERICAN ISTHMUS CANALS.

BY JOHN D. ESTABROOK, MEMBER CIVIL ENGINEERS' SOCIETY OF ST. PAUL.

[Read April 3, 1893.]

The object of this paper is to bring together what seems of interest in considering the proposed deep waterway; not so much to present new matter, as facts that have been established by others at various times and places.

In developing a scheme for any great public improvement, it is wise to first make a broad reconnaisance and seek answers to several questions like the following :—

Is there a demand for the proposed work ?

Is it likely to get enough business to make it servicable to the community ?

What experience has been gained elsewhere that will help us here ?

What obstacles, physical or financial, are we likely to encounter ?

What will be its cost and what is likely to be its revenue ?

The subject of better water-way communication between our Great Lakes and the Atlantic seaboard was thought of enough importance to warrant calling those interested to a National Convention recently held for that purpose in the city of Washington, D. C.

Those interested in railways (and who to-day is not ?) have asserted

that hereafter the railway,—not the canal, is to furnish the world's inland transportation.

For fifty years railways have been forging ahead at a wonderful pace, not only in the way of extension, but of improvement as well. Railway freight rates have been reduced to one-fifth their former price and one fiftieth the old wagon-road rate. Canal improvements have not meantime been so marked.

The charge now for transferring grain from lake vessel to car or canal boat at Buffalo, N. Y., is as much as for 500 miles of lake transportation. The charge at the seaboard for transfer from car to Atlantic steamer is about the same as for lake transportation from Duluth to Buffalo, a distance of 1100 miles.

Freight rates so far as the public are concerned, are defined in schedules that give the price per 100 pounds between named terminal points: but those whose duty it is to prepare these schedules must keep in mind the equivalent rate per ton-mile. The latter standard is the only one that admits of general comparisons, and is, consequently, the one we shall here use.

The following freight rates on grain for 1891 and '92 are in fractions of a cent per ton-mile.

All rail from Minneapolis to New York,	.49 to .54
Lake and rail from Minneapolis to New York,	.44
Canal boat from Buffalo to New York,	.18 to .35, average .26
Whaleback-boat by lakes from Duluth to Buffalo,	.06 to .12
Atlantic steamer from New York to Livervool,	.03 to .13, average .07
Sailing vessel from California to England (4 months' time),	.04

For convenience we may therefore say, for all rail, half a cent; for Erie Canal, a quarter of a cent; and for deep water, a half mill per ton-mile, that is, the long distance deep water-way rate is about one-tenth the long distance rail rate. It is but fair to state here, however, that heavy terminal expenses must generally be covered by the freight rate and that, consequently, the longer the distance without change or transfer the less the rate per ton-mile will be increased for terminals.

The above by no means proves the advisability or practicability of a deep water-way outlet for the Great Lakes, but it does invite to further investigation, and points towards a ship canal that will accommodate vessels of 3,000 to 4,000 tons for continuous trips between Duluth and New York without change of load,—vessels that will take as much wheat as is usually demanded by the ocean steamer. It is clear

that we need continuity of line, and, except for manufacturing purposes, the transfers should be restricted to one at the farm, one at the Lakes and one at the seaboard.

Now let us see what modern experience in the way of ship canals elsewhere will teach us.

SUEZ.

The most notable example is undoubtedly the deep water-way across the Isthmus of Suez.

This Isthmus, in latitude 30° to 31° north, or about like Galveston and New Orleans, is a comparatively level, sandy, and generally a rainless desert, 72 miles wide, connecting Asia with Africa, and separating the Mediterranean and Atlantic on the north and west from the Red Sea, and Indian Ocean on the south and east.

This is the Biblical "Land of Goshen", and at that time, 1400 B. C., must have had a more humid climate.

The modern Suez canal has, however, done much toward again ameliorating the parched condition that for a time existed. Records indicate that as early as 1400 B. C., there was a waterway from the Nile to the Red Sea; that in 270 B. C., this waterway was certainly navigable, and that in A. D. 767, the ancient canal was finally and permanently closed by order of Al Mansover.

On the western bank of the Nile opposite the great temple of Karnak, is the smaller temple of Queen Hatasu containing on its walls elaborate illustrations of the expedition of five seagoing vessels and 200 men from Thebes to the "Land of Punt," and their return laden with gold, ivory, amber, precious incense, gums, etc. The Land of Punt is supposed to be the eastern-most point of Africa bordering on the Gulf of Aden and the Indian Ocean; easily reached by way of the canal and Red Sea, but practically inaccessible for such vessels by way of Gibralter and Cape of Good Hope. Queen Hatasu reigned about 1500 B. C., and it seems altogether probable that the ancient canal was in use at that early date.

This ancient canal was repeatedly closed by drifting sand, and repeatedly re-opened. It is said to have been 92 miles long, 150 feet wide and 15 to 30 feet deep. The magnitude of this ancient work compares favorably with Egypt's temples and pyramids.

The subject of a modern Suez Canal was an international question for years. England always opposed it. Napoleon I. ordered a survey in 1798, which by some error made the Red Sea thirty feet higher than the Mediterranean and gave rise to fears that its construction might inundate the Nile Valley. This belief obtained for nearly half a century. In 1847, France, England and Austria joined in a commission to examine and report on the Canal. Robert Stephenson was the English representative and he condemned the canal scheme because of the

drifting sand. Ten years later the Sepoy revolt caused Lieut. Waghorn to make a forced trip between Bombay and London in thirty days. The English then lost no further time in securing the completion of a railway from Alexandria to Suez. In 1856 Ferdinand de Lesseps invited a large number of foreign experts to examine and report some canal scheme. The three English representatives joined in favor of a canal with locks at each end and with its bed 25 feet above sea level, while all the continental experts agreed upon the plan which was adopted for a canal without locks and with its bed 27 feet below the sea level.

Ferdinand de Lesseps was born in 1805, served in the French Consular service and as minister to Spain till 1849, when he resigned to give his attention more completely to the Suez enterprise that had already interested him for years.

Neither the Sultan of Turkey nor Viceroy Abbas of Egypt would then give attention to internal improvements. It was not till Mahomet Said Pasha succeeded Abbas as viceroy in 1854 that de Lesseps felt encouraged. Then he lost no time in dramatically presenting his pet scheme to the new ruler and promptly received an exclusive charter or concession for 99 years.

"La Compagnie Universelle" was chartered both in France and Egypt with a capital of $40,000,000—400,000 shares of $100 (500 francs), of which the viceroy took nearly one-half (176,602 shares). He further conceded the right of way, together with lands that could be irrigated from a fresh water canal, and agreed to furnish enforced Fellah labor necessary for the canal work.

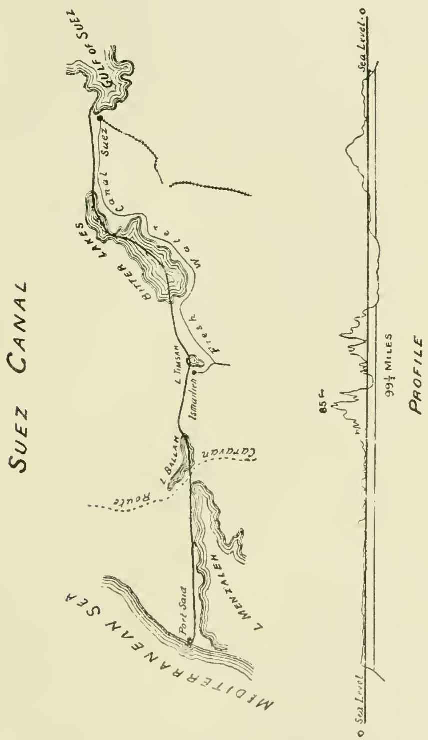
Ground was broken at Port Said, the Mediterranean end of the canal, April 29th, 1859, and the canal was officially opened for public use ten years later, Nov. 17th, 1869, water having been let in from the Red Sea in the preceding August and from the Mediterranean in the preceding February.

Thus after 60 years of continued agitation; ten years of labor with improved machinery; the use of abundant capital and the unflinching support of the viceroy who was a notorious spendthrift for public improvements, and all this in a country containing the Nile valley where arable land can year after year pay a tax of $5.00 per acre, and under the leadership of de Lesseps who was undoubtedly able as a diplomat and financier, this great work was at last accomplished. Did we not look back to what had been done by the hand labor of a barbarous people thirty-four centuries earlier, we might boast of this achievement in the 19th century.

The modern canal does not follow the line of the ancient structure which started from one fork of the Nile some distance from its mouth.

M. de Lesseps took advantage of existing salt lakes and beds of evaporated lakes that were below sea level. Joining these he cut

thence south to Suez and north to the Mediterranean where he formed the artificial harbor of Port Said by projecting from the shore into the sea two piers or jetties 6,000 and 7,000 feet in length and made of 22-ton blocks of artificial stone. At the shore the piers are nearly a mile apart, and at the outer end less than half a mile. The artificial stone was made from the native sand and French hydraulic lime, the blocks



being allowed to season some months before immersion in the sea. The harbor at the Suez end was also improved and a depth of 28 to 30 feet of water established.

Much uncertainty was felt about the permanency of a Mediterranean harbor by reason of the immense deposits that the Nile annually brings

(estimated at 36,000,000 cu. yds.), and that are swept by prevailing winds in the direction of Port Said. Experience for 15 years shows some decrease in sea depths beyond the end of the piers, but thus far there has been no serious silting at the harbor entrance.

The profile of the canal shows high land near the middle of the Isthmus with a summit 85 feet above the sea level. Nearer the Red Sea is a lesser summit and some rock where blasting was necessary, though for the recent canal enlargement, this rock was broken by stamping in preference to submarine blasting. The profile is remarkable, showing, as it does, so large a proportion of the natural surface below the sea level. Eight miles of the way were through old lakes where no dredging was needed, 16 miles more needed but little dredging and only 66 miles were in canal with bordering banks on both sides. For 11½ miles the depth of cutting was 50 to 102 feet. Through portions of the lakes where there were no bordering banks the channel was marked on both sides by iron beacons anchored at intervals of 250 ft.

The total length of the improvement is 99½ miles and the total excavation before enlargement about 100 million cubic yards. The canal was first opened for vessels not exceeding 5,000 tons burthen, 400 ft. in length and 50 ft. beam. The water-way section had a depth of 26 ft., bottom width 72 ft., top width 197 to 325 ft., depending on the nature of the material. Side slopes rose from the bottom one foot in two feet to a plane five feet below the water surface and from thence rose much more gradually to provide effectually against destructive wave action. Widenings were made at intervals for tieing-up and passing vessels. A speed of 5.8 miles per hour was permitted.

At one time as many as 30,000 laborers, mostly Egyptians, but really a Babel of nations, were employed on the excavation, but during the blockade of the southern ports of the United States at the time of our civil war, the price of cotton became such as to induce the viceroy of that date to transfer his canal force to cotton fields and in 1864 work on the canal was practically suspended. Arbitration was resorted to and Napoleon III, as arbitrator awarded to the company and the viceroy paid nineteen million dollars for the surrender of the labor and land concessions that the previous viceroy had granted. Then machinery had to be substituted for human labor and 60 huge dredgers costing $100,000 each were soon at work.

Objection to the canal had long been urged that it would be merely a stagnant, unhealthy ditch soon obstructed with sand and the lakes with salt. Experience proves nothing to be feared from that source. A tide of 5 to 6 feet at the Suez end is felt for a distance of 14 miles and then loses itself in the Bitter lakes. From Lake Timsah, the midway station, there is a slight but constant current to the Mediteranean where very little tidal action exists.

The tolls have been reduced from $2.24 to $1.90 on vessel tonnage and $2.00 on passengers not counting the shipmen. The saving in distance from going round Cape of Good Hope is 3600 miles between New York and Bombay, and 4840 miles between England and Bombay. The $1.90 toll on vessel tonnage is equivalent to about 3,000 miles of ocean transportation, though it is double the amount for which wheat is sometimes taken by steamer 3,000 miles from New York to Liverpool. The saving by the canal is therefore in time rather than in freight charges. The time consumed in transit of vessels through the canal was at first from two to three days, but that has since been reduced to one day, or about 17 hours steaming time.

One of the necessary preliminaries to the modern canal was a supply of fresh water for the men. This was obtained from the Nile by opening a fresh water canal 6 feet deep and 60 feet wide, from Cairo to Ismailia and thence to Suez. A pipe for fresh water was laid from Ismailia to Port Said.

In providing capital for any great work it is necessary to furnish not only what the work legitimately costs, but in addition thereto interest on all capital used for the time there is no revenue, aud discounts and commissions allowed on bonds and securities sold. In the case of the Suez Canal the first 40,000,000 in shares may have paid for the work, but meantime the interest account amounted to as much more and the discount of 40 per cent. on bonds sold and the cost of a lottery scheme to place other bonds further swelled the capital.

In 1887 the capital account had reached $97,611,004. The original 400,000 shares to the viceroy and public, and 10,000 additional shares to the founders were different from ordinary American stock; that is, stockholders were entitled from the first to interest @ 5 per cent. the same as on bonds. That part of the revenue left after paying running expenses and interest was called the surplus. This surplus was divided as follows: 71 per cent. went as an additional dividend to shareholders, 15 per cent. to the Egyptian government, 10 per cent. to the founders, 2 per cent. to the managing directors and 2 per cent. to the invalid fund. In 1885 the total revenue was $13,009,939. Expenses $6,204,236.

Surplus $6,805,753 which gave to the shareholders in addition to their 5 per cent. interest a dividend of 12 per cent. Some years the shareholders have received in all 18 per cent. on their investment.

In 1884 it was decided by the company to proceed with the enlargement of the canal. Engineers had recommended a bottom width of 230 feet on tangents and 262 feet on curves at an estimated cost of $49,-250,000 for a depth of 27 feet and $54,000,000 for a depth of 30 feet.

There had been some talk of making two parallel canals, one to lead south, the other north, but it was decided to have one wide channel and to commence by widening 50 feet on the African side, increasing

the depth to 28 feet, and increasing the limit of speed from 5.8 to 7½ miles per hour. Lately electric lights have been supplied. In 1890, 83 per cent. of the vessels did not tie up at night, and the average time in the canal for the same year was 24 hours and 6 minutes.

After opposing the canal for generations, and after the work had been completed at a cost of nearly $100,000,000, and had proved successfull, the British Government in 1875 obtained control of the enterprise by purchasing from the Khedive 176,602 shares for $20,000.000 and thereby secured a majority vote of 10 in the organization.

The English managers dismissed a part of the operatives and substituted other nationalities in place of an exclusively French corps; made the canal open to merchant and naval vessels of all nations; made neutral a circuit of three miles at each entrance port, and made neutral in case of war so much width of contiguous territory throughout the line, as a commission, already provided for, shall then determine.

The growing business of the canal is shown by the following tabular statement:

YEAR.	NO. VESSELS.	NET TONS.	TRAFFIC RECEIPTS.	PASSENGERS.	PASSENGER RECEIPTS.
1870	486	436,609	$ 869,151	16,758.5	$ 52,710
1871	1,765	761,467	1,519,077	48,422.5	96.844
1872	1,082	1,160,743	2,875,418	67,640.7	135,281
1873	1,173	1,367,767	4,170,145	68,030.8	136,061
1874	1,264	1,631,650	4,533,558	73,597.4	147,190
1875	1,494	2,009,984	5,286,158	84.446.5	168,893
1876	1,457	2,096,771	5,526,291	71,843.5	143,686
1877	1,663	2,355,447	6,036,185	72,822.5	145,645
1878	1,593	2,269,678	5,669,134	99,209.8	198,419
1879	1,477	2,263,332	5,426,223	84,512.8	169.024
1880	2,026	3,057,421	7,298,522	101,551.7	203,103
1881	2,727	4,136,779	9,438,776	90,524.8	181,049
1882	3,198	5,074,808	11,084,208	131.068.6	262,137
1883	3,307	5,775,861	12,111,697	119,177.2	238,354
1884	3,284	5,871,500	11,725,751	151,916.6	303,833
1885	3,624	6,335,752	12.011,452	205,951.3	411,902
1886	3,100	5,767,655	10,954,215	171,411.5	342,823
1887	3,137	5.903,024	11,119.059	182,997.6	365,995
1888	3,440	6,640.834	12,966,454	183,895.7	367,791
1889	3,425	6.783,187	13.233,516	180,594.7	361.188
1890	3,389	6,890,094	13,396,800	161,353.8	322,707
1891	4,206	8,699.020	16,684,300		

The nationality of the vessels using the canal in 1890, as shown in the following table was 80 per cent. English :—

	SHIPS.	GROSS TONNAGE.	NET TONNAGE.
German	273	731,877.8	490,587.7
American	3	2,111.6	1,051.4
English	2,522	7,438,681.7	5,331,095.3
Austrian	55	177,941.3	118,047.0
Brazilian	1	1,119.3	634.9
Spanish	34	103,111.5	70,172.7
French	169	555,941.3	365,904.2
Greek	3	2,682.0	141,851.9
Italian	87	217,480.0	143,721.1
Japanese	4	6,300.5	3,784.3
Netherlands	144	341,828.2	248,511.8
Norwegian	43	78,107.0	57,416.4
Ottoman	21	28,302.9	19,880.1
Portuguese	27	3,814.1	22,247.5
Russian	20	59,613.1	35,073.1
Siamese	1	206.7	115.0
Totals	3,389	9,749,129.0	6,890,094.4

The report for 1890 shows:—

Total Receipts	$14,092,182
Charges of all kinds	6,465,505
Net earnings	$ 7,626,677

The gross annual revenue from this 100 miles of line has now reached nearly $20,000,000 yielding to shareholders in addition to their 5 per cent. interest an annual dividend exceeding 10 per cent. The annual gross earnings are almost 20 per cent. of the total capital including first cost interest, accumulations, discounts and commissions.

The construction of the canal has proved to be as great a commercial benefit to the world as it has been financially beneficial to its promotors.

England did what she could to discourage the enterprise, but when she discovered its succcess she lost no time in securing its control and aiding in its further development. The $20,000,000 she paid to secure control is about equal to the present annual revenue. She received 176,602 shares of a par value of $17,660,200 but the annual income from these shares had previously been pledged to the canal company till the year 1894. The construction of the canal not only revolutionized the commerce of England, but completely changed the plans and proportions of her steam vessels.

International jealousy and fear of invasion caused the intentional destruction of the ancient canal. It remains to be seen if an alliance between selfishness and ignorance will at any future time close the present great highway.

Let us now look at the

AMERICAN ISTHMUS.

Tehuantepec, Nicaragua, Panama, San Blas and Attrato. This neck of land has a most irregular coast line on both the Atlantic and Pacific sides.

Its width varies from a minimum of 30 miles at San Blas to hundreds of miles at other points. From Tehuantepec in southern Mexico to Nicaragua in Central America the general curve of the land is toward the southeast, but from the latter point to the Attrato River, where the land broadens into South American States there is a reverse curve with a general trend to the east, in latitude 9° north, say 600 miles north

THE AMERICAN ISTHMUS

of the equator and about 1400 miles further south than Suez. All the proposed points of crossing except Tehuantepec are therefore in the depths of the tropics, under a climate subject to extremes of heat, moisture and malaria, and capable of consuming human energy and human life to an unlimited extent. After four centuries of attempts by the Spaniards to settle this country the white population is now about 10 per cent. of the total.

The annual rainfall on the Isthmus tablelands varies from 70 to 150 inches but at some of the Alantic coast points it has been as much as 24 feet per year. 300 inches or 25 feet was the rainfall at Greytown in 1890.

In place of a sandy desert as at Suez we here find a country producing tropical fruits and choice woods in abundance. The great con-

tinental divide known south as the Andes and north as the Rocky mountains here appears near the Pacific coast as a schistose volcanic ridge greatly varying in height and character; with slopes of clay, gravel, ashes and mixed alluvium and containing streams and rivers that rise 40 feet under the influence of tropical rains.

Generally in the Gulf of Mexico and Caribbean Sea is found drifting sand described as so unstable that at some points islands appear where a frigate could have floated a few years before. Tropical calms and tornados occur, and earthquakes and volcanic shocks are not unheard of. Tides on the Atlantic side are generally less than 2 feet while on the Pacific side they vary from 17 to 27 feet.

West of Panama, a broad expanse of the Pacific ocean, subject to calms is popularly known as the "Doldrums." Years ago Lieut. Maury of "Sea Geography" fame announced that if by any convulsion of nature a ship channel should be opened through the American Isthmus, sailing vessels would still brave Cape Horn rather than venture by Panama. This was an extravagant statement, but still it was not unusual in 1849-50 for sailing vessels to consume ninety days in a trip from Panama to San Francisco.

Lieut. Maury advised Ship masters to first sail southwest as if for Callao, and when near the equator to bear west till the southeast trade winds were encountered when it would be possible to take a northerly course direct for San Francisco. Of late American Captains take advantage of every breeze to get their vessels further west regardless of gain or loss in a northerly course, and thus make the trip in thirty that formerly took ninety days. The commerce of the world has however, changed and the sailing vessel is no longer the most important carrier. Steamships defy calms and gales.

The desire of the Europeans for a western route to the Indies led to the rediscovery of America five centuries ago by Columbus and to the rapid exploration of the new continent. In 1513 Balboa and his party climbed the Cordilleras at Darien and brought the first report of the near existence of the Pacific coast. In 1519 Cortes landed at Mexico and during his reign there, ordered a survey for an interoceanic canal at Tehuantepec. In 1520 Angel Saavidra made the earliest proposition to pierce the Isthmus. In 1550 Antonio Galvao suggested four routes, one at Panana and one at Nicaragua. In 1695 the Scottish Parliament chartered a company for trading with Africa and the Indies. William Patterson, founder of the Bank of England, was leader. It is recorded that in Scotland, "Subscriptions sucked up all the money in the country." In December 1698 Patterson with 1200 colonists landed at Darien to found there "an Emporium for the commerce of the world." Six months later a miserably sick and weak fragment, all that was left of the colony, re-embarked on three vessels ready to sail

anywhere and by any means that would take them from a place of so much suffering. Only Patterson and a handful of his followers lived to again reach their native land.

In 1814 the Spanish Cortez ordered the viceroy of New Spain to build the Tehuantepec canal, but war for independence upset the plan.

1849 to '55 witnessed the building of the Panama Railway as an American enterprise. Under the patronage of the United States Government various canal explorations and surveys were made on the Isthmus from 1870 to 1876 when a report was finally made to the President favoring the Nicaragua route.

About the same time Europeans caused explorations to be made, and in 1879 an International Congress was held in Paris to receive reports and make recommendations. This congress considered plans for four different routes. No. 1 was the Attrato route. It followed up the Attrato river south 149 miles thence west by canal 31 miles, and by tunnel 5½ miles. It contained two locks and a tide-lock to the Pacific. Difficulty in navigating the Attrato in times of flood caused the rejection of this plan. No. 2 was at San Blas (near Panama) only 30 miles in length, but it required 7 miles of tunnel and had inferior harbor facilities at the Pacific terminus. It was therefore rejected. No. 3 was at Panama, an open cutting 47 miles in length at sea level. This route was recommended as the most favorable. No. 4 was at Nicaragua; starting from Greytown thence by the San Juan River, Lake Nicaragua and a canal to the Pacific. Total length 180 miles with 20 locks. This route was rejected.

The distances by different routes between important seaports are as follows:

	San Frans. to New York.	San Frans. to Liverpool.	New York to Hong Kong.	Liverpool to Hong Kong.	Liverpool to Auckland.
	miles.	miles.	miles.	miles.	miles.
Via Cape Horn..	15,687	15,800	20,379	20,606	13,897
" Panama.....	6,063	8,885	12,953	16,471	13,312
" Tehuantepec.	4,890	8,276	11,602	15,253	12,809
" Cape of Good Hope..			16,945	15,722	16,222
" Suez Canal..			13.596		16,045

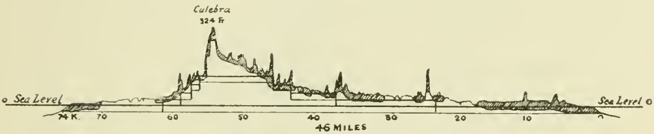
It appears from the above table that American ports are to be the chief gainers from a canal across the American Isthmus. The Panama route will save 9,600 miles between San Francisco and New York, 6,900 miles between San Francisco and Liverpool, 600 miles between China and New York, and nearly the same between New Zealand and Liverpool.

PANAMA.

In 1878, the Colombian government granted to "The Civil International Interoceanic Canal Society" an exclusive concession to build a canal through the State of Colombia by the Panama route.

After the report of the Paris Congress of 1879 in favor of the Panama route, Ferdinand de Lesseps, then 74 years of age, consented to lead the enterprise, and in 1880 he inspected the route and reported favorably. He organized the "Universal Inter-oceanic Panama Canal Co.," capital $120,000,000. $20,000,000 was the price paid for the old charter, leaving $100,000,000 for working capital.

PANAMA CANAL



NB The parts shaded had been excavated when work was suspended in 1888

PROFILE

The route started from the Bay of Limon on the Atlantic side; thence up the valley of the Chargres river, thence up its tributary, the Obispo, thence through the Culebra Pass by a cutting 9½ miles in length with its summit 324 feet above sea level, and thence down the Rio Grande to the Pacific. It was to be a sea-level canal with 26 feet depth of water in earth and 29½ feet depth in rock. Bottom width 72 feet in earth and 78¾ in rock. Half the excavation was estimated to be rock. Total cost estimated at $165,000,000. Subsequent estimates increase the total excavations from 100 million cu. yds. to 176½ million cu. yds.; and made the cost $350,000,000. One of the structures incidental to opening the canal was a dam across the Chagres river over a mile in length and 150 feet high at one point.

Steam dredging machines were engaged to excavate at both ends of the canal and steam excavators along the line. Work was commenced

in 1882, but from the start there was much trouble in placing the securities and in raising funds necessary to prosecute the work. People engaged in the enterprise seemed to soon loose not only their energy, but their honesty as well, and by 1887 instead of having the work nearly completed, Lieut. Rogers, of the U. S. Navy, reported less than one-third completed and 7 years more time needed.

As a measure of immediate relief the company decided to change the design and lessen the excavations by 85 million cu. yds. They adopted a canal with a central portion 125 feet above sea-level reached by four locks at each end, with lifts varying from 26¼ to 36¾ feet. A contract for 10 locks to be completed by 1890 was made with M. Gustave Eiffel. The French government was further asked to sanction the issue of $120,000,000 in lottery bonds, but after some investigation this request was refused: work on the canal stopped; De Lesseps resigned and the Tribunal of the Seine appointed judicial liquidators. The expenditures up to June 30th, 1885, had been $154,509,082. A commission appointed by the receiver in 1890 reported $180,000,000 additional funds needed to complete the work as a lock canal and estimated the annual cost of maintaining the canal when completed, at $2,000,000; net annual receipts from $2.40 per ton toll, $7,600,000 for first three years, and $12,200,000 afterwards, value of work done and material on the ground, $90,000,000. They further recommended that maritime nations should guaranty the interest on the necessary securities.

Thus far nothing toward resumption of work has been accomplished and the present prospect is not hopeful.

Americans, always jealous of any European foothold on this continent, have persistently held aloof from this enterprise, notwithstanding its success would benefit them commercially more than any other people.

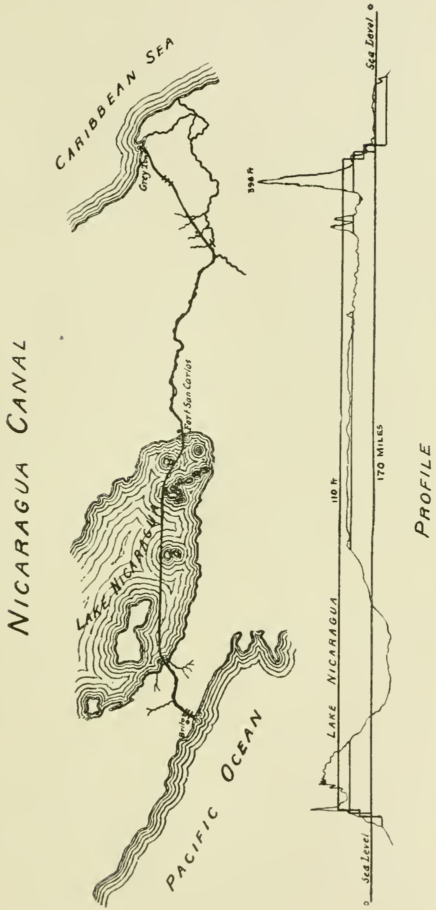
Quite recently the French Government has condemned to prison M. Fredinand de Lesseps, now a feeble minded man 87 years of age. I certainly shall not be surprised to learn that the French Government has raised a monument in the streets of Paris to the memory of this same Ferdinand de Lesseps.

NICARAGUA.

About 400 miles west and 150 miles north of the Panama route is Lake Nicaragua.

Some years ago an exclusive concession was granted to an American company for a transcontinental canal by the way of Lake Nicaragua. In 1885 this concession was renewed to a second American Company and work was commenced at Greytown in 1889. February, 1889, the U. S. Congress chartered "The Maritime Canal Co. of Nicaragua,"

requiring that the president and a majority of the directors shall be citizens of the United States.



Starting from near Greytown this route ascends the valley of the San Juan River by dams and locks to Lake Nicaragua 110 feet above

the sea level, and from the lake descends by locks to Brito on the Pacific at the mouth of the Rio Grande. Length 170 miles, of which only 30 miles are canal and 140 miles lake and artificial basins. Estimated cost $50,000,000. Time required for construction 6 years. To provide means for the $50,000,000 estimated cost of construction, the Maritime Canal Co. at one time proposed to issue $100,000,000 in stock and $155,-000,000 in bonds. Now there is an endeavor to get the United States government to guarantee $100,000,000.

At Brito it is proposed to build three locks rising from the Pacific ocean 110 feet to the lake level, and thence through the continental divide by a cutting nine miles long to Lake Nicaragua. This pass through the continental divide is only 41 feet above the lake level or 151.4 feet above the ocean and is, consequently, the lowest pass on the Isthmus.

Though the depth of cutting through this divide west of the lake is comparatively light there is a much deeper cutting required through one of the more eastern ridges of rock. Proceeding to the southern end of Lake Nicaragua the lake level is further extended in that direction by building the Ochoa dam across the San Juan River; other dams across tributaries of the same, and cutting through the divided ridges and through the eastern ridge to the main slope that faces the Caribbean Sea. The total length of the summit level as proposed is nearly 145 miles and the locks are assembled near the Atlantic and Pacific ends. It is estimated that a vessel can make the entire trip in 30 hours and that 32 vessels can be accommodated in one day. The canal is to be 80 feet wide at the bottom and 80 to 343 feet at the top.

Little progress has thus far been made in the actual work of constructing a canal at Nicaragua. Some of the physical peculiarities of the region are not prepossessing. In the Pacific coast-range of Nicaragua are twelve prominent and several minor volcanic peaks. Some of these are still active. In 1835 one spread ashes from the City of Mexico to Bogota, over a radius of 750 miles. North of Nicaragua, in Mexico, the average annual temperature in some of the Pacific towns is 102° Fahr, while towns on the Gulf of Mexico are subject to yearly visits of yellow-fever and black-vomit.

TEHUANTEPEC.

The proposed ship canal at Tehuantepec has not of late received favorable attention on account of its great length, its summit level of 732 feet above the sea; its 140 locks, and its insufficient water supply.

In 1884, James B. Eads obtained for this route a concession for a ship railway that he had perfected from an earlier design by Channing of Rhode Island. In 1888 "The Atlantic and Pacific Ship Railway Co." with a capital of $50,000,000 was organized in New York. Work was to commence within a year from June 1st, 1888, and to be completed

within five years, but nothing has thus far been done. Capt. Eads plan contemplates at each terminal seaport, a narrow ship-receiving dock open to the railway at one end and to the harbor at the other. At the bottom of this dock is a submerged pontoon, which can be raised or lowered by pumping water out or in. The pontoon has tracks like the railway, and supports on the tracks a carriage, so constructed, that, when by raising the pontoon the carriage comes in contact with the ship, it will automatically fit the ships bottom and by means of springs evenly distribute the weight. The pontoon, carriage and ship are raised by hydraulic power till the pontoon tracks connect with the fixed tracks 30 feet below sea level. The railway has twelve tracks, 4 to 5 feet apart, and the carriage has 1,200 wheels, each to carry 5 tons or a total of 6,000 tons. A stationary engine hauls the carriage and ship from the water. Two specially designed locomotives then take them the balance of the way, at a speed of 10 to 12 miles per hour, up a maximum grade of 1 per 100 and over a summit 726 feet above the sea. Three changes of direction are made by turntables in place of curves in the track. Meeting trains pass by means of transfer tables. Critics estimate the weight of the loaded vessel and carriage at 26,000 tons; too heavy a dead load to be safely started and hauled 10 miles per hour.

Fifty years ago a portage railway 30 miles in length successfully conveyed loaded canal boats across the mountains of Pennsylvania. Soon a trial is to be made of a ship-railway to convey coasting vessels of 1,000 to 2,000 tons across 15 miles of land that connects Nova Scotia with New Brunswick. This will take vessels by an inland route from the Bay of Fundy to the Gulf of St. Lawrence and shorten the distance more than 500 miles. Two locomotives on tracks 18 feet apart are to be used.

Ship owners and underwriters will continue to look with suspicion on ship railways till their success has become assured. Unfortunately the operating of the ship railway device demands the most intelligent and constant supervision. Failure in any link destroys, for the time, the whole chain of communication.

All attempts to build transcontinental canals have been met with international suspicion in place of active help. Capital is always conservative and suspicious of novelities. A whisper from certain quarters will often make or break the immediate success of an important work. To successfully start a project a wise promoter is often more needed than the best engineering ability.

There is need for a ship channel or like means for crossing the American Isthmus. The world demands this, but it is not particular about its exact location or who builds it. One will sometime be built and after ten years will pay a large income on its legitimate cost; but the scheme needs the financial support of a strong government. Dis-

count, commission and preliminary interest will amount to a load greater than the labor item for construction.

In a country subject to seismic disturbances, where the climate is such as to constantly sap man's health and energy it is specially desirable that the canal when completed be as free as possible from mechanical devices, and for that reason, a salt-water, sea-level ditch with tide gates only, is greatly to be preferred. The obstacles are appalling in magnitude rather than in character. Could the work that is centered in 20 miles of tropical country be spread over a breadth of 2,000 miles in a northern country it would be accomplished in three years.

Seated in our library, 3,000 miles from the scenes of operation, we can undoubtedly build the canal far more satisfactorily to ourselves than if we had spent a year on the ground.

Ever since M. de Lesseps paid to the holders of the exclusive charter for a canal at Panama $20,000,000 in money, "cold water" has been freely poured upon the enterprise and leeches without number have sucked the life blood from the Panama Canal Construction Company.

Promoters of the Nicaragua scheme acted perhaps more wisely. Instead of paying money, which at no time has been abundant, they paid to the holders of the exclusive charter for the Nicaragua route $12,000,000 in the capital stock of the Maritime Canal Co. This stock is valuable or valueless in proportion to the success or failure of the undertaking.

So long as this stock is in the market an active interest in the Nicaragua enterprise is likely to continue.

Were it possible to eliminate personal greed till the joint action of the governments of the United States, England, France and other important nations could be secured in favor of what may be determined to be the best Isthmus ship-canal for the commerce of the world, the same to be neutral to all, we might then hope for speedy success.

Capital, immense in amount and commanding the confidence of all financial centres will be needed rather than the support of a few bought by enormous commissions and retaining fees.

It should be remembered that for many years, the ablest experts proved to their own satisfaction the impracticability of successfully building and maintaining a sea-level canal at Suez. Still we have lived to see such a canal built and operated continuously and with wonderful success for the past twenty-three years.

Again, the idea of transporting freight by railway trains at a speed of 15 miles per hour was ridiculed by those thought to be the best able to judge, now four times that speed is not uncommon.

There are several other important examples of modern ship canals and a review of them would be of service in this connection, but the length of this article already, admonishes us not to wander further.

ERIE CANAL.

Let us now return to our original proposition for a deep water-way from the Great Lakes to the Hudson.

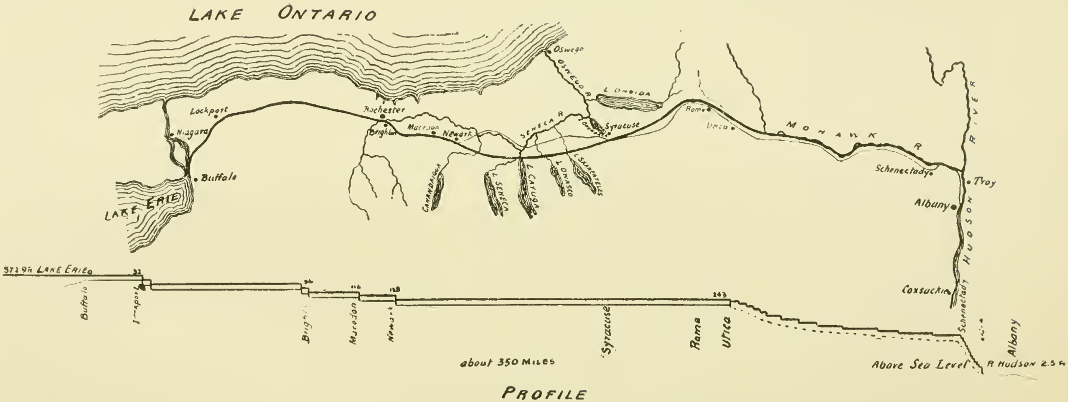
Data for making a definite location and estimate of the cost is not at hand, but we do know in a general way something of the physical character of the region. Geologists tell us that ages before the days of Queen Hatasu and the ancient Suez Canal there exsisted a continental water course from the lake region, and Mohawk and Hudson valleys to an outlet some 40 miles south-east of New York City. The bed of this ancient channel was above the sea level, quite unlike the present Hudson from New York to Albany which is a tidal arm of the sea. The time was before the Alleghany mountains had been thrown up, but not before the Adirondacks and the Canadian hills existed.

Lake Erie is now 572.9 feet above the sea and the divides separating the Lake waters from those of the Mohawk and Mississippi are but slightly above the lake level. It is therefore physically possible to restore in a measure the ancient water course or to establish a deep lock-controlled water-way fed from the Great Lake system and emptying into the Hudson River. Such a water-way should have a lock depth of 20 feet and a general depth approaching 25 feet, with a right of way 1,000 feet wide where practicable. This would involve deepening some reaches in the upper 30 miles of the Hudson, and a canal or artificially deepened water-way across the state of New York about 345 miles in length.

Going east from Buffalo the present Erie Canal starts with a depth of 9 feet, then diminishes to 7½ feet and finally to 7 feet toward Albany. The 2 feet extra depth at Buffalo is demanded by reason of a 4 foot rise and fall in the water surface of Lake Erie.

In 1884, Mr. Sweet, a member of the American Society of Civil Engineers, and one thoroughly familiar with the general features of the present Erie Canal and its surroundings, read a very interesting and instructive paper before the society, in which he discussed the proposition for deepening, widening and extensively improving the canal, and making it a deep water-way with a continuous easterly flow from the Lakes to the Hudson. It should be borne in mind that the Falls and Rapids of Niagara represent a drop of 328 feet in the Lake channel between Lake Erie and Ontario, and that a considerable extent of Central New York, drains into the lower lake. Fortunately for our canal scheme, this interior plateau rests on an elevated bench of limestone and its larger drainage-streams fall in cascades 200 to 300 feet in their descent over the edge of the limestone, as in the vicinity of Rochester and Utica. The present canal responds by locks to this midway depression, but for the proposed larger canal, if it dropped to the lower level, the

ERIE CANAL


LAKE ONTARIO
Oswego
OSWEGO R
L ONEIDA
Lockport
Rochester
Niagara
Brighton
Macedon
Newark
SENECA R
Syracuse
Rome
Utica
MOHAWK R
Buffalo
LAKE ERIE
CANANDAIGUA
L SENECA
L CAYUGA
L OWASCO
L SKANEATELES
Schenectady
Troy
Albany
HUDSON RIVER
Coxsackie
372.9 ft LAKE ERIE
32
94
116
128
243
Buffalo
Brighton
Macedon
Newark
Syracuse
Rome
Utica
Schenectady
Albany
about 350 MILES
Above Sea Level
R Hudson 2.5 ft
PROFILE

tributary streams could not supply sufficient water for lockage purposes.

It is therefore necessary to maintain a continuous easterly flow from Lake Erie to the Hudson. Mr. Sweet's proposition is for a canal not less than 18 feet deep, and 100 feet wide at the bottom, with locks 450 feet long and 60 feet wide. Starting from Buffalo it proposes that the present canal line shall practically be followed to Newark, a distance of 130 miles, the present canal being deepened, widened and straightened. The 1st or Lake level will extend 32 miles from Buffalo to Lockport where will be two locks of 25 feet. 2nd level, 64 miles from Lockport to Brighton, and 2 locks of 24 feet. 3rd level, 20 miles, from Brighton to Macedon, and one lock of 20 feet. 4th level, 12 miles, from Macedon to Newark, and one lock of 20 feet.

5th level, 115 miles, from Newark to Utica. This 5th or Rome level will probably demand an entirely new location, partly south of the present canal, south of the Clyde River, and crossing over the Canandaigua outlet and over the Seneca River near its junction with the outlet from Cayuga Lake. This latter crossing, (over the Cayuga Lake outlet) for a length of 2 miles, will be on an embankment 40 feet high, and is the most formidable obstacle met with throughout the line. East from Utica the Mohawk River is to be followed by deepening and building dams and locks 10 to 12 feet high at intervals of about 5 miles. From the mouth of the Mohawk, at Troy, to Four Mile Point in Coxsackie, 30 miles, the channel of the Hudson River will have to be narrowed and deepened.

Mr. Sweet estimated the cost of this improvement at 125 to 150 million dollars and the annual tonnage at 20 to 25 million.

It may be here stated that the vessel tonnage of Lake Superior alone as registered at the "Soo" canal in 1892 was 11,240,000, or nearly equal to the gross tonnage from all sources passing through the Suez Canal.

What this Lake Superior tonnage is destined to become when the country tributary to that Lake has become developed as that tributary to Chicago has been developed in the past thirty years, and what this increased tonnage when added to the tonnage from the other great lakes will amount to when it reaches the proposed canal from Buffalo to Albany can scarcely be estimated.

At the time Mr. Sweet's paper was read, nine years ago, freight rates per bushel on grain from Chicago to New York, averaged, during the season of navigation as follows: for all rail $14^9/_{10}$ cents; for Lake route to Buffalo and rail thence to New York $12^1/_{10}$ cents, and for Lake route and Erie Canal $9^9/_{10}$ cents per bushel. Lake vessels carried grain from Chicago to Buffalo for 2 cents per bushel while the Erie Canal rate (including Buffalo transfer) was 4 cents per bushel for half the distance though it took double the time. By the proposed improved water-way,

grain can be taken from Chicago to New York in less time and for less money than it is now taken from Buffalo to New York, that is for 4 cents per bushel in place of $14^{9}/_{10}$ cents per bushel by rail.

Probably the earliest publication advocating an Erie Canal was a stirring pamphlet written by Jesse Hawley in 1807-8 while he was in prison for debt in Ontario County N. Y. Gouverneur Morris was about the only one who took a serious view of the matter; most people treated it with ridicule. Water transportation was then in ascendancy. June 30, 1817, a six ton schooner was reported at Cincinnati, Ohio, from Rome, N. Y., June 1, bearing its owners in search of land in the Wabash Country. It had made the voyage by way of Wood Creek; Oneida Lake; Oswego River; Lake Ontario; a portage of 11 miles around Niagara; Lake Erie; Cattarnaugus Creek; a portage of 8 miles, and thence by the Alleghany River and Ohio River.

The present Erie Canal was opened in 1825 for boats carrying 60 tons; it was enlarged in 1836 for boats of 240 tons; since then it has remained without further material improvement. In 1850 a railway train carried 200 to 250 tons; in 1893, 1,131 tons of paying freight had been carried in one train from Buffalo to New York.

In fifteen years, 1868 to 1883, the tonnage of the Erie Canal fell from 6,442,225 to 5,664,056 or a decline of nearly 800,000 tons, while for the same period, the tonnage of the New York Central, Erie, and Pennsylvania railways increased more than fourfold or from about 10,500,000 to 46,100,000, an increase of nearly 36,000,000. In 1888 the freight carried by the Erie Canal was classified as follows;

Flour and grain	34 per cent.
Coal	23 " "
Forest products	22 " "
Other mine products . . , . .	11 " "
Miscellaneous	10 " "

The railway interest is represented by enormous corporate capital, always active, always aggressive, while the active Canal interest is mostly restricted to individuals of moderate means. The discussion of Mr. Sweet's paper in 1884 brought out statements in effect that railways can now transport freight cheaper than canals; that railway rails now occupy the bed of one abandoned canal, and that that kind of transformation is likely to be extended; that parallel tracks can be added to present trunk railways and carry freight at the minimum price, and that capital is ready for an indefinite multiplication and extension of railways, but cannot be secured for canals.

No attempt was made to account for the fact that lake boats were actually carrying grain at a profit from Chicago to Buffalo for two cents per bushel when the railroads require eight cents for similar service.

To-day rail rates from Duluth to New York are $5.80 to $7.00 per net ton, and lake and canal-boat rates between the same points are $2.00 to $2.67 per ton.

In the absence of definite surveys, and without the intimate local knowledge possessed by Mr. Sweet, it would be foolish to attempt to improve upon, or to criticise Mr. Sweet's plan. We can only add that experience at Suez since the date of his paper, clearly indicates a tendency toward a steady increase of ship-canal cross-section, and that a depth of 20 feet is now as clearly demanded as 18 feet was then.

Need for this deep waterway is as urgent for national defense as for commercial purposes. If at any time we should be so unfortunate as to get into trouble with our neighbors on the north, canals on their ground already give them gunboat communication from the St. Lawrence to the Lakes, while we, without a deep water-way on our soil, would be shut out and our lake towns would be at the mercy of the enemy and subject to a possible damage exceeding the full cost of the canal.

The United States Government should therefore make the necessary surveys and location, and the State of New York should freely give the full right of way and pay all damages for derangement of local business consequent upon building the canal.

The increase in export business for the city of New York, resulting from opening this water-way would soon be quite sufficient to warrant the payment of $10,000,000 for right of way and damages.

It does not seem wise to make tnis canal a huge political machine by asking either the state or nation to build it. A corporation under proper limitations can build it more economically and operate it more successfully.

Its most serious burden will be its interest account during the time of construction and for the few succeeding years that will be necessary for the diversion of business from old channels and the adaptation of transportation to the new route. The nation's proper share of the expense could well be pledged for this purpose. Suppose the United States Government should appropriate to the enterprise for interest paying purposes for a period of ten years, as follows: for the 1st year $1,000,000, and increasing $1,000,000 annually to $5,000,000 for the 5th year, then the same amount of $5,000,000 for the 6th year and decreasing $1,000,000 annually to a final payment of $1,000,000 on the 10th year. By this time the canal and its business revenue would have become sufficiently established to insure ample means for meeting all current expenses and annual sums for sinking fund and betterments. The aggregate appropriations by the government would in this way be $30,000,000 to be given outright upon pledge from the corporation to promptly complete and operate the canal, or in case of failure to forfeit

all claims. The $30,000,000 to be given, as above, by the general government is about equal to the amount contributed by Egypt to the Suez enterprise, and is the estimated revenue from the completed canal for a period of one and a half years.

We have been passing through a cycle of wonderful railway building for domestic commerce and the same is yet to continue. But we are approaching a time when we must also share in the business of the world in the way of exports. Our grain must successfully compete with that raised in India and Australia. The people of America demand that, practically, the wheat fields of the Red River Valley of the north shall be as near to New York as those of the Mohawk Valley were a few years ago. This can be and must be done.

The construction of the deep water way will not divert business from the railways so much as it will do business that the railways cannot do, and that otherwise would not be done. We have seen that the tonnage of four great trunk lines entering New York tripled in amount in fifteen years.

The immense business waiting for the new water-way, estimated at 20 to 30 million tons per year and increasing rapidly, can profitably pay a toll of $1.00 per ton till such time as Congress shall establish a lower rate.

A gross revenue of $20 000,000 thus obtained would be sufficient to pay all current expenses, interest, sinking fund, enlargement etc., till at the expiration of the charter, or the cancellation of the stock the canal should become the property of the United States.

Business seeks the great commercial centers and convenience for cheap transportation will first be made in channels leading to these centers.

Today freight can be sent from Mississippi River points to New York, and thence to Japan or China, for less money than it can be sent direct to the Pacific coast and thence to its destination.

Grain is now being taken from New York to Liverpool for one-fifth the rail rate from Minneapolis to New York, though the former distance is about two and a half times the latter, that is the rail rate is twelve times the ocean rate per ton mile. For years we have been too much absorbed in other pursuits to give much attention to matters of this nature, but competition is now driving us to it, and we shall soon be compelled to make use of all rightful means within our reach.

Systems of great inland water-ways penetrating to the centers of our grain producing states are to be built and to be used largely for carrying material for export. but there will yet remain for the railways an abundance of business of a more local nature that can profitably pay better rates. The business of our railways multiplies so rapidly that the companies are forced to annually secure greater ter-

minal facilities. This acquirement of additional territory in our larger towns cannot go on indefinitely. The local business will in time practically absorb all railroad transportation facilities, leaving through business for other carriers.

The first advance step in inland transportation is the pack-animal, chiefly in use on steep mountain paths; the second is the common road wagon, for more general use: the third is the railway car, for use almost as general, and the fourth is the large steam vessel, its use restricted to deep water-ways, either natural or artificial.

The profitable application of the latter means is capable of vast extension in this country.

The following statistics are of interest in this connection:—

"SOO" CANAL.

Year.	Amount of Traffic. Regist'd Tonnage.	Flour, bbls.	Wheat, bus.	Other grains. Bus.
1855	106,296	10,289		
1856	101,458	17,686		33,908
1857	180,820	16,560		22,300
1858	219,819	13,782		10,500
1859	352,642	39,459		71,738
1860	403,657	50,250		133,437
1861	276,639	22.742		76,830
1862	359,612	17,291		59.062
1863	507,434	31,975		78,489
1864	571,438	33,937		143,560
1865	409,062	34,985		229,926
1866	458.530	33,603		249,031
1867	556,899	28,345		285,123
1868	432,563	27,372		323,501
1869	524,885	32,007		304,077
1870	690,826	33,548	49,700	308,823
1871	752,101	26,060	1,376,705	445,774
1872	914,735	136,411	567,134	309.645
1873	1,204,416	172,692	3,119,997	149,999
1874	1,070,857	179,855	1,120,015	250,080
1875	1,259,534	309,991	1,213,188	407,772
1876	1,541,676	315,224	1,971,549	343,542
1877	1,439,216	355,117	1,349,728	264,674
1878	1,667,136	344.599	1,872,940	951,496
1879	1,677,071	451,000	2,603,666	2,574,106
1880	1,734,890	523,860	2,105,920	367,838
1881	2,092,757	605,453	3,456,965	473,129
1882	2,468,088	344,044	3,728,856	776,552
1883	2,042,259	687,031	5.900,473	517,103
1884	2,997,837	1,248,243	10,985,791	422,981
1885	3,035,937	1,440,093	15,274,213	715,373
1886	4,219,397	1,759,365	18,961,485	775,166
1887	4,897,598	1,572,735	23,096,520	2,022,308
1888	5,130,659	2,190,725	18,596,351	2,133,245
1889	7,221,935	2,228,707	16,231,854	2,044,384
1890	8,454,435	3,239,104	16,217,370	1,032,104
1891	8,400,685	3,780,143	38,816,570	
1892	11,240,000			

The chief articles carried through the "Soo" Canal were as follows:—

Ore	3,560,000	tons.
Coal	2,407,000	"
Grain	1,170,000	"
Lumber	550,000	"
Flour	375,000	"
Iron	70,000	"
Copper	99,000	"
Salt	41,000	"

The canal season was in 1891,—225 days, and 10,191 vessels of all kinds passed.

In 1892,—233 days, and 12,580 vessels of all kinds passed.

It closed December 7, 1892. The increase in the business of 1892, compared with 1881 was as follows:—

Grain, 61 %. Flour, 43 %. Iron, 38 %.

The cost per ton mile for carrying freight on the Lakes has been as follows:—

1887	$0.0023
1888	0.0015
1889	0.0015
1890	0.00103
1891	0.00103

The new lock at the "Soo" will require three more summers for its completion, and $5,000,000 is its estimated cost. At a mean stage of water in Lake Superior the new lock will have a depth of 21 feet at the miter-sills. It is 800 feet long and 100 feet wide, and will admit of the passage of four of the largest lake vessels at once.

LIST OF LAKE SUPERIOR "WHALEBACK" BOATS.

FEBRUARY, 1893.

No of Vessels.	Length, feet.	Beam, feet.	Depth, feet.
1	220	25	18
2	260	36	22
4	284	36	22
7	264	36	22
3	264	38	24
8	292	36	22
4	320	38	24
1	340	42	25
2	320	42	25
32			

The larger boats carry 2650 tons of freight when drawing 14 feet of water. Lately the practice has been to put steam machinery into about one-third the vessels built on the "whaleback" plan.

Last season out of 16 vessels built, eleven were barges and five were steamers. One steamer has towed three loaded barges.

CHICAGO.—NUMBER AND TONNAGE OF LAKE VESSELS.

YEAR.	ARRIVALS		DEPARTURE.	
	Number.	Tonnage.	Number.	Tonnage.
1887	11,950	4,323,292	12,023	4,421,560
1888	10,989	4,393,768	11,106	4,496,898
1889	10,804	5,102,790	10,984	5,155,041
1890	10,507	5,138,253	10,547	5,150,665
1891	10,225	5,524,852	10,294	5,506,700

Records give the number of packages of incoming and outgoing freight, but in many cases not the weights. The weight of a few of the items can be estimated and these alone amount to five million tons.

In 1891 the seven trunk-line railways carried from Chicago to points east of the Ohio River, 2,556,624 tons of dead freight (of which 378,049 tons were for export) and 1,400,000 tons of live stock and beef, or a total of 3,957,295 tons, against 4,595,440 for the year 1890.

For the five years ending in 1862 with railway freight rates at 2.5 cents per ton mile in gold, 54% of the flour shipped from Chicago went by Lake. Similarly for the five years ending in 1884, with railway rates at 0.8 cents per ton mile, 15½% went by lake and the balance by rail.

MILWAUKEE.—NUMBER AND TONNAGE OF LAKE VESSELS.

YEAR.	ARRIVALS.		DEPARTURE.	
	Number.	Tonnage.	Number.	Tonnage.
1887	5,174	2,362,065	5,202	2,349,350
1888	5,288	2,469,765	5,330	2,515,850
1889	5,565	2,901,417	5,596	2,870,657
1890	5,377	3,010,196	5,329	3,147,144
1891	5,942	3,593,039	5,784	3,510,846

The incoming freight for 1890 was 1,706,903 tons, and for 1891,—2,155,311. The outgoing freight by lake for 1890 was 655,149 tons, and for 1891,—761,167 tons; the incoming and outgoing freight for the port was about three millions.

ANNUAL RECEIPTS OF FLOUR, WHEAT, CORN, RYE, BARLEY AND OATS AT PROMINENT WESTERN CITIES.

In tons of 2,000 pounds.

YEAR.	Minneapolis.	Duluth.	Chicago.	Milwaukee.	Detroit.	Toledo.
1887	1,426,000	658,000	4,119,000	763,000	350,000	672,000
1888	1.403,000	423,000	4.384.000	775,000	317,000	345,000
1889	1,351,000	763,000	4,494,000	748,000	278,000	383,000
1890	1,536.000	759.000	5,312,000	917,000	288,000	662,000
1891	1,927,000	1.483,000	5,609.000	1,003.000	350,000	897,000

The crop of the United States for 1801 is estimated by the Agricultural Department as follows:

Wheat, 18,358,400 tons: corn, 57,684,312 tons: and oats, 11,814,304 tons: total, 87,852.016 tons.

AMOUNT OF FOOD EXPORTS FROM PROMINENT AMERICAN ATLANTIC PORTS.

In tons of 2,000 pounds.

YEAR.	Flour.	Wheat.	Corn.	Beef, pork, lard	Butter, cheese	Total.
1884	751,218	1,752,149	821,225			
1885	795,902	939,102	1,703,232			
1886	843,521	1,838,831	1,544,386	479,967	55,416	4,762,121
1887	1,099,899	2,409,658	918,056	473,695	46.894	4,948.202
1888	911.327	675,798	647,502	437,229	49,234	2,721,090
1889	817,868	599,883	2,154,712	513,371	50,252	3,136,086
1890	918,017	670,481	2,223,229	756,513	62,562	4,630,802
1891	1,088,103	2,698.322	719,292	787,453	48,661	5,341,831

The ports included are Montreal, Portland, Boston, New York, Philadelphia and New Orleans, but fully 50 per cent of the total goes from New York. Say three million tons from New York for 1891.

An American authority in a recent article advocating free trade gives the value of the foreign commerce per capita in different countries as follows:

United States, . . $ 26

France and Germany, . 54

Great Britian, . . 100, and states that Great Britian alone has half the foreign commerce of the world, employing 6,000 steamers and 11,000 sailing vessels.

From all this we are to infer, I suppose, that the adoption of free trade would quadruple the foreign commerce of the United States.

The cost of transportation by railway at different periods is given in tabulated form as follows:

The amount of traffic is in million ton-miles.

The freight expense and profit in cents per ton-mile reduced to gold basis.

NAME OF RAILWAY.	Year.	Amount of Traffic.	Freight Rate.	Operating Expenses.	Profit.
N. Y. Central.......	1865	320	2.5	2.0	0.50
" "	1870	769	1.25	0.79	0.46
" "	1883	2400	0.74	0.53	0.21
Lake Shore & M. S..	1870	574	1.0	—	—
" " ..	1883	1700	0.73	—	—
United Ry's of N. J..	1892	—	—	1.00	—
Penn. Ry. in Pa.....	1892	—	—	0.40	—
English Ry's........	1892	—	2.40	—	—

WORK FOR OUR ENGINEERS' CLUB.

By Robert Gillham, President, Engineers' Club of Kansas City.

[Read March 13, 1893.]

In accepting the Presidency of the Engineer's Club, I do so with a feeling that I have been greatly honored by its members.

This is an age of progress, an age marked for its extended mastery over natural forces. Great undertakings of commercial, as well as engineering importance, are almost constantly before the public in some form or other.

In Europe we have the great canal connecting the Baltic and the North Seas, now under construction, of great commercial and military importance to Germany. In Holland the draining of the Zuyder Zee, by which nearly 600.000 acres of land will be re-claimed. To the south of us, we have the great Nicaragua Canal, that will, no doubt, be built and controlled by the United States Government. Turning to Russia, we note the commencement of the great Trans-Siberian Railway, that will, when finished, complete the Steel Belt across the Russian possessions, from St. Petersburg to the Pacific Ocean. This great enterprise will certainly be one of the greatest elements in the development, and civilizing of Siberian territory.

We have Prof. Langley, Chanute, Maxim, and other eminent engineers and scientists earnestly engaged in efforts to solve the problem of aerial navigation. The facts that these men have drawn from nature by means of most thoroughly conceived experiments holds our in-

terest, and tends to encourage the hope that the problems associated with aerial navigation will, at no very distant day be solved.

In electrical engineering, our thoughts return, when the subject is mentioned, again and again, to Edison, Bell, Prof. Thompson, and other noted electricians, but above them all, at this time, we find our thoughts centered on Mr. Tesslar, who has thus far astonished the world by most wonderful experiments, which tend to change many of the accepted theories regarding electricity.

While these experiments have not led to anything that, at this time seems practical, yet we cannot but believe that we are on the eve of wonderful developments based upon the discoveries of Mr. Tesslar.

We can thus view the domain of scientific research and find new discoveries that tend to broaden our knowledge of nature, and its operations, so little understood in the early part of our history.

Great discoveries, and a more intimate and accurate knowledge of natural law, and the forces that maintain nature, have a tendency to liberalize the human mind, and thus, in almost every department of human knowledge we find investigators and reformers at work, working out untold benefits to the human race.

As a result; liberality on the part of the people, is marked in the consideration of reforms advocated by men eminent in their calling.

We do not find, in this age, the expert at work, hiding from the eyes of the curious in some remote corner of a cellar, or the extreme rooms of an attic, fearing that his knowledge and discoveries may be stolen and used by others.

There was a time, however, when many men kept their knowledge to themselves. Most often through selfishness, but many times on account of the fear they had of the punishment that superstition might invoke.

We should be thankful that we live in this age, when men and women are willing to give to the world the best results of individual effort in all departments of human knowledge, without fear, and without cost.

Many are unable to give to the community money whereby hospitals, libraries, and charitable institutions may be founded, but we can give a portion of our time, of our energies, of our thoughts, without expecting any other compensation save that which is found in the fulfillment of duty.

We all owe something to the community in which we make our home.

I care not whether you are blest with higher education, experience, observation and travel, riches, or with only a small portion of this world's goods.

When we review the history of this century, we find that among

the best thoughts, and those that have very largely contributed to the good of the world, and improvements in the methods of manufacture, and inventions unpatented, that have cost the world nothing, have added more than we can estimate to the happiness and progress of the race.

Therefore, I urge, you, gentlemen, educated in special lines, performing special duties in the world, and qualified and capable of performing a service for the community that you, as engineers, contribute thought, time, study and energy to the up-building, the improvement and the reforms demanded in our city, and thus add your contribution in attempting to improve and better the conditions of the city we are pleased to call our home.

These great and interesting scientific subjects referred to, attract us, but we can do the world and the community greater good than we can estimate, by giving consideration to the problems associated with the development and building of Kansas City.

Modern city building is a matter of vital importance, and in the improvement and development of improved methods in city building, the engineer plays a very important part.

In almost every department of city building, the engineer exercises an influence.

It is with a view of interesting you in matters that relate to the physical improvement and beautifying of Kansas City, and in the study of all local problems that relate to your profession, and in establishing the best methods in the execution of public works in our city, that I address you on this subject, at this time.

The opinions of the Engineer's Club, if based upon careful investigation, will command respect in the community.

Not long ago the subject of building a new water-works was considered by our city government, that embraced the expenditure of many thousands of dollars, which, if carried out according to recommendations, would have caused disappointment and involved radical changes in the plan, before a successfully operated and desirable system of water-works could have been secured, and in addition, an expenditure of a much larger sum of money than was estimated. This is a field that offers interesting inducements for a very thorough and complete investigation by our engineers.

In the matter of street improvements there is much to be learned.

The lack of uniformity in the improvement of our streets is not blamable entirely to the city government, but is largely due to the indifference of the tax-payers. When street improvements are suggested, there is usually inaugurated a series of competitions between paving companies, who represent special pavements, and individual property holders, many of whom desire the cheapest, rather than the most dura-

ble pavement, and who consider the laying of the pavement as an expedient, rather than an improvement demanding the greatest utility. In other words, we find on some of our most important streets, advocates of brick pavements, of macadam, of gravel roads, when nothing but the higher types of pavement should be considered.

I need not pass, at this time, upon the various pavements suitable for a city like ours, but when a street is improved, the improvements should be of a uniform character throughout, based upon a comprehensive system of general street improvements.

Take the matter of side-walks, an important element in beautifying the street.

On one of our most important residence streets, you can find in one block stone flagging, in the next block cement side-walks, in the next an irregular wooden side-walk, with irregular grades, rotten planks, and unprotected areas.

A street like this should have uniformly laid first-class side-walks, with proper margin of grass plat between the curbing and footway. There is no excuse for this marked neglect of our side-walks. You may look in any direction in our city and you will find similar conditions.

The present administration has done much to improve these defects. I have often thought, on many of our residence streets where the street traffic is light, that the side-walks could be greatly increased in width, reducing the road-way, and with properly arranged foot-way, and grass plat between the curbing and the foot-way, and with a liberal planting of shade trees, resulting in changing streets that are now unattractive side streets into pleasant and attractive park-ways.

We should not adhere to the rule, in all cases, that the side-walks should be one-fifth of the width of the street.

In the matter of curbing we have much to learn. There is absolutely no uniformity in this matter. Curbings are indifferently set, and of varying widths and lengths.

Curbings would be much better if made eight inches wide at the grade line, instead of four or six inches.

In the matter of sewerage, we have great problems to face, problems that have not been solved, and if allowed to remain unsolved will sooner or later plunge this city into an epidemic that cannot well be described.

Nature has favored our city in many respects, and particularly in the matter of surface drainage.

There are many problems associated with the O. K. creek sewer, which is costing the city thousands of dollars, and which have not yet been solved. Here we had, years ago, a little stream, gathering the waters from numerous springs, and taking the rainfall within its drainage area, pure in those days, as pure as the mountain stream. In

the course of time, the city expands its territory, sewers are built, and in time the volume of sewage is increased, all of which is directed and discharged into this little brook, which, as years go by, brings about a pollution that is, at this time, a disgrace to the city, and ourselves.

When the sewers were first directed into O. K. creek, years ago, and the foul matter allowed to flow into it, then was the time that marks the birth of this great evil, that we are now compelled to submit to.

The remedy will not be found in the conversion of this creek into a great mammoth sewer, part of which has already been built, mammoth because the rain-fall within the area drained by this creek, demands that this sewer shall have a fixed capacity in order to carry off the immense volume of water gathered within its banks.

Sanitary requirements was not the scale by which the dimensions of this sewer were determined. A sewer six feet in diameter running parallel with the general direction of this creek, and intercepting the sewers running north and south, would have been ample to have taken the sewage from the habitations of our people, and would have prevented the pollution and the evil which we are now compelled to endure.

It is not my desire to criticize what has been done, neither is it my purpose to try to indicate the mistakes that may have been brought about by the building of this sewer.

The solution of the sewerage question, as applied to the O. K. creek valley, is yet to be solved. The engineers who have dealt with this problem in the past, have in many respects, been compelled to assume and continue the plans of their predecessors and it would be manifestly unfair to too severely criticize or condemn the work already accomplished, as there may be reasonable grounds for difference of opinion.

We are here, not for the purpose of criticizing, but for the purpose of suggesting, and if possible, by our suggestions in the future bring about sufficient data upon which the consideration of the extension of this particular system may be based.

The question constantly presents itself, how are we finally to dispose of the sewage gathered in this territory.

Is it more desirable to reach the Missouri River by means of a tunnel under the city, discharging the sewage below the city, or is it better to carry the sewage around into West Kansas, and thence to the Missouri River, or into a general intercepting sewer following along the entire river front of our city, discharging the accumulated waste a mile or more below the city, in the Missouri River. We have also an important problem in determining the question of final disposition of Kansas City, Kansas, sewage.

Imagine, if you please, the constant growth of Kansas City, Kansas, with its large manufacturing enterprises, of all descriptions, the sew-

age gathered from thousands of homes of Kansas City, Kansas, and many homes of Argentine, all discharging their accumulated waste into the Kansas River, a stream, the velocity of which, during a large part of the year, is so low that it can hardly be measured, and whose volume during the low stages of water, foretells a pollution of this stream that will develope a greater evil than the O. K. creek pollution.

This is a problem worthy of the consideration and attention of our best engineers. What can be done to prevent the discharge of sewage into the Kansas River? Is it possible, that, by means of conducting the sewage to a common point, where it can be pumped to a higher level outlet sewer, and conducted along the banks of the river, to a point near its mouth, then by syphon under the river to connect with the suggested intercepting sewer along the river front of Kansas City, Missouri.

How is this problem to be solved? How are we to prevent the pollution of the Kansas River, due to the great acquisition of population west of the Kansas River?

We all enjoy taking our friends to the beautiful suburb, Hyde Park, where we find modern homes, supplied with modern improvements, drives that are park like in their general make up, and attractive in all respects. What has been done with the sanitary question as applied to this district?

Has the problem been solved? How long is this method to continue without having a definite and comprehensive sewer system designed? There are many ways by which this district can be served by sewers. The question is, is it better to establish sewage works for the utilizing of the sewage, or is it better to follow the plans adopted in the O. K. creek case, and discharge the sewage into Brush Creek, thus creating an evil, the penalty for which, will be visited upon the inhabitants in that district in the shape of all manner of fevers, impairments of health, and in many cases, death.

This is another interesting question that merits the attention of the Engineers' Club. We are compelled to note the rapid acquisition of railways in the last few years, and as time rolls by this number is certain to be added to each year. There is an excellent opportunity for the study and consideration of the overhead and undergrade railway crossings, associated with the lines entering our city. We do not, at this time, feel the evil effects of grade crossings, but the time will come when we will awaken to the sense that this important part of city building has been overlooked. There is a strong sentiment in most communities in favor of the establishment of electric conduits throughout the city streets, and compelling the laying of all telegraph, telephone, and electric light wires in these conduits, thus getting rid of the unsightly poles of varying heights and appearances. Here we

find an important problem. How shall these conduits be built, maintained, and regulated. By the city or by private corporations?

A city cannot be much of a city and occupy a high position among improved modern cities, if the city streets are allowed to accumulate dirt, paper and all manner of foreign accumulations?

Clean streets will do more with properly maintained sidewalks and pavements, in creating a favorable impression than any one thing These are matters that can be observed and seen by every individual using our streets. There may be defects in the sewers, connections and inlet basins may not be properly trapped, but the general public know nothing of this, for the reason that these defects are below the surface of the streets, and are hidden from view; but with the streets, it is different.

The ordinary theatrical sign boards are perhaps among the most striking nuisances a city has to contend with.

After a shower of rain, tragedians, ballets dancers, prima donnas, and men from the minstrel show can be seen peeling from these boards, and blown into the streets, and whirled around from place to place increasing the disfigurement and filth upon the streets.

In Europe, as well as in this country, we find the progressive cities contending with the smoke question. Many extensive experiments have been tried, and are being tried with the view of solving the problem. This is a serious problem in that it is almost impossible to maintain the standard of cleanliness, while the smoke nuisance prevails. It is desirable that we have information as to what is being done in other cities towards the solution of this problem, and there are members in our Club who are competent and capable of making thorough investigation and giving the Club the benefit of their studies in this direction.

Take the question of Parks and Boulevards. When I think of the beautiful city of Edinburgh, of their rugged bluffs, palisades, and deep ravines treated in a most artistic manner with grass and flowers, trees, terraces, and winding walks, artistic bridges, and ivy faced rock, I feel ashamed of the small effort that our city has made in availing itself of those conditions that nature has liberally bestowed. I say it without fear of contradiction, I do not believe that any city in this country has been better favored in opportunity in this respect than Kansas City.

Think of the high bluffs to the north and east of our city, and beautiful sites to the south, that only await artistic treatment to develope most attractive drives, parkways, terraces and those essentials that go to make these choice summits beautiful.

Take the bluff opposite the Union Depot. If the park, which was at one time proposed by the Board of Public Works, had been completed, with its fountains, its rustic seats, sparkling springs, playing

fountains, shady nooks, winding paths, and terrace upon terrace, no advertisement that this city can make would equal the direct good that this park would have done. Many persons, who have neither the time, nor the opportunity to come up into the city, pass through the city at the Union Depot, and their impressions of the people and our methods are based to some extent upon the impressions gained from that picture represented by the shanties, and dog coops, and chickens and ducks running around and about the face of this unsightly bluff.

In this direction the energies of the engineer will find a great opportunity for benefitting the community in assisting in the solution of the question the parks and boulevards.

The garbage question is a question that is closely allied to the profession of engineering. The experience of other cities may be studied with profit, and the method of final disposition be determined after these investigations have been thoroughly completed. We find in the question of city lighting many interesting questions, that relate to the practical operation of gas and Electric light plants, and the question of municipal ownership which, at this time, demands the attention of our citizens.

Methods that relate to the execution of public works should be seriously studied, and the best method of securing the highest class of inspection, as well as the highest character of work.

We now come to the Surveys of our city, a subject of great importance to the property owner. It is too often true that one Surveyor will give the location of a lot or street line, and the next Surveyor give a different one, involving the question of valuable frontage, and oftentimes resulting in serious and expensive litigation. There should be established a basis from which all surveys should be made. and that would avoid these errors and differences. Should the city have a resurvey, in part, or as a whole? What is the best method for city surveying that will insure accuracy? These questions can all be thoroughly considered by the Club. In all this work the engineer may not find a very great compensation, but he owes it to the community, that he gives it something, some of his best thoughts, his time, and energies in trying to improve the community in which he lives. The indifference of most people is the curse of modern times. It is felt in politics, it is felt in all religious works, it is seen in social work, it is seen in all phases of municipal improvement. This is perhaps more generally observed in the west than in the eastern cities.

There is greater energy in the west, but with that energy, the disposition to make temporary things serve the purpose of permanent things, is more generally observed.

This is wrong. In New England in the smallest towns, if a man fail to paint his house occasionally, he is usually looked upon as de-

generating, going back, that there is something wrong with him.

If the flowers are absent from the front door-yard, the house wife is not so well as usual. The paint on the house, the green blinds, the little flower garden, the ivy covered rockery are the evidences of refinement and interest.

The important thing in any community is to create sentiment in favor of improvements. If one man keeps his house well painted, well repaired, and the grass kept short, the trees trimmed, and flowers cultivated, it is not long before his neighbor is taught a lesson, and while he may not immediately follow the example, he will begin by first trimming his trees, then the grass is cut occasionally, finally the house is repainted, and the flowers planted, and before they realize it themselves, they have improved and beauitfied their property, and so it goes from one to another, until it becomes fashionable, the thing, the proper thing, to have nicely kept lawns, beautiful flowers, well kept trees, grass borders between the street and the side-walks. Side-walks well washed and kept clean, and thus it is that the people in the aggregate in the community have so much to do with the general appearance and attractiveness of the city. This indifference is the thing we must try to change. We should try to convince people that there is something outside of their homes and home attractiveness that needs their attention.

That there is something outside the books on their library shelves, in which they can find enjoyment, if they will.

That there is something outside of the pictures that hang on the walls in their homes, and that they should take a little of the art and a little of the order, and try to fit it in with public improvements associated with our city building.

I hope this year will be marked with definite accomplishments of the Club in all departments that relate to city building.

It will be the policy of the Club to ask its members to give some of their time and their energies to the consideration of subjects that relate to improvements in our city. These subjects will be alloted at the proper time, and it is my desire that there may be an earnest and hearty response upon the part of the members, showing their willingness to take part in this meritorious work.

NOTES ON THE PROPER CRITICAL ATTITUDE ARCHITECTS AND ENGINEERS SHOULD ASSUME IN ATTENDING THE WORLD'S FAIR.

By Chas. W. Hopkinson, Member Civil Engineers Club of Cleveland.

[Read May 9, 1893.]

Solomon was wise above his fellows; but his confident inquiry,—"Is there anything whereof it may be said, 'see this is new;'" and his dogmatic negative answer, find scant confirmation among the beholders of the almost miraculous panorama of the living present. It is the new that dazzles us. Through the combination of the various elements of nature, and of the numerous forms of the physical world, man has, in later years, tremendously increased his power to create forms of beauty and works of utility.

To the development of these powers, nothing has so greatly contributed within the last forty years, as the great world-embracing fairs, that at unequal intervals have been held on one or the other of the two great continents. To my mind, the Columbian Exposition will not only meet the expectations of the world, but should be considered in itself as one of the greatest achievements in the history of civilization.

The world has seen many important projects successfully brought to their proper completion:—The building of the great circuses, baths and amphitheatres of Roman times; the great Byzantine buildings of Eastern Europe; the immense cathedrals of Gothic and Renaissance periods; and the great bridges, ship railways and canals of modern days.

The glory and power of the entire period of the Caesars produced comparatively few great monuments. It took the accumulations of the christian churches to build the great cathedrals; while the great engineering feats of modern days have been simply masterstrokes of individual genius, along comparatively straight lines of development.

The world's Columbian Exposition, great as it is, is not the last great throe of modern civilization. It is rather the joyous bringing together of tithes to the world's store-house: not alone in honor of the discovery of the Western continent, but as a happy token of the peace, plenty and advancement of civilization of the world. It is not a single achievement, but rather a combination of achievements, which has not in the slightest perceptible degree diminished the wealth of the nations contributing. It is a symposium not of one subject, but of many—of engineering, architecture, statuary and painting, mining,

electricity, agriculture, transportation and the liberal arts.

The Dublin World's Fair of 1853, had one of the finest displays of paintings ever gathered together. The Vienna Exposition of '73 was a supurb exhibition of industrial arts. The Paris World's Fair of 1867, was the most gorgeous in the line of royal guests and pageantry; yet, except in this last particular, which will not count for much in free America, the present World's Fair promises much more in every branch of industry, art or skill.

To engineers and architects the exposition will mean more than to many others attracted to Chicago for amusement, general observation or instruction. We all shall find much to amuse and instruct us; but as professional men in special lines, how are we to receive what we see?

Some there are who have eyes and see not; who having ears, hear not. We must not emulate these, but should leave our draughting rooms, offices and constructions with senses keenly alive to our opportunities, and with minds fairly open to receive all that we can retain, and carefully weigh what we observe.

Our posthumous criticisms of the World's Fair—what are they to be? What prejudices and arbitrary rules as to how this or that should be, and preconceived notions are to obscure the visions disclosed to our view at the Fair, and convert them into distortions as gnarley and stunted as the little half developed trees and shrubs that grew on the sandhills of Jackson Park before man undertook its transformation?

There is a very objectionable method of criticism which some people adopt in forming their judgments. Let me illustrate: A man having a very fine apple orchard, of which he was justly proud, asked a visitor, who was of profound critical power and discernment, what he thought of his apple orchard. "Well," said the friend, "I never *did* like apple orchards, *I* like pear orchards!"

It is such criticism as this which we should guard against. Let us confine ourselves to a judgment of the things actually presented to us. Many of the conditions governing the Fair were fixed before the architects, engineers and landscape artists took hold of the problem. Our engineering problems are given us, we do not make the conditions. We endeavor to skilfully work them out and reduce the disadvantages as far as possible. So has it been at Chicago. Let us therefore endeavor to separate the conditions imposed by the problem itself, from those which were left to the individual judgment and then judge of the skill in the handling of these conditions, in utilizing and harmonizing them with the high conception of the needs of a World's Fair in a perfect sense. If we can go to the fair in this spirit will we not receive thereby the greatest possible profit and enthusiam and be in a condition to truly and honestly judge and appreciate and if necessary criticise the greatest Fair of any age?

First let us inquire what should be our attitude towards the general appearance of the grounds. The prairie or plains about Chicago afford very different conditions from those of Fairmount Park, Philadelphia. The latter showed marks of vegetation of many years growth. Jackson Park was nearly a swamp, so swept by the cold winds from the lake, that only scrub trees abounded. This alone will give the Columbian Exposition a different aspect from what we might wish. Nothing so softens architectural form, however beautiful it may be in itself, as stately trees, which hide parts here and there, and make possible such glorious vistas, as we see, in connection with many of the cathedrals of England, where, immense as are the buildings, the effect is wonderful as viewed from adjacent hill, dale, pond or river. In the wisdom of congress it was thought best to have the Exposition inland; and many things determined its choice of an inland city except the strictly aesthetic conditions. Chicago being selected as the proper place at which to hold the Fair, it required great wisdom to locate the site—railroad facilities without tracks on the grounds, approach by boat, sufficient extent of territory, and many other conditions, had to be met. Let us not ask therefore "could not a different site have been chosen which would have more easily loaned itself to Fair purposes" but rather "Has the problem, which the requirements of the Fair imposed been solved in the most thorough and thoughtful manner?"

A Frenchman who recently visited Chicago said, in his report to the Paris Society of Civil Engineers: "The French exhibition of 1889 was compact, symmetrical, and built according to the majestic *ordinance* of a general plan conceived in advance," and further on he said: "The American exhibit is gigantic, and is not built according to a rigid and uniform plan. On the contrary it leaves so considerable a portion to each ones whim that the plan is hardly visible and one would be tempted to deny the existence of any." Let not such talk mislead us, and above all, let us wait until we have carefully looked over the ground before endorsing it. In the meantime, we should examine carefully the map of the grounds and see if we can discover the plan of the designers. Let us note the great plaza seven hundred feet wide and a thousand feet long, with the lake at one end, and the entrance depot at the other, and the Administration Building in the center.

We shall observe the grouping of the buildings bordering the plaza; and the lagoon containing Wooded Island stretching away to the north with the great buildings on either side; while at the north end we shall find the Art Building surrounded by the state buildings. With some such anaylsis of the plan, let us reserve further judgment until the reality is visible, and we can see the vistas planed over Wooded Island and from the lake and the railroad station. Then shall we be able to say whether or no the the whole is "symme-

trical and built according to the majestic *ordinance* of a general conceived plan in advance."

There is likely to be much criticism of the Fair, because of the manner of selecting experts. Instead of having a public competition for the landscape gardeners and architects, it was all done by a careful selection of the men on their general reputation. Some have said that this would produce a revel of individual fancy undesirable, or compel the directors to so restrict the different designers as to produce an effect of stifled effort and a stiff and ungraceful result generally.

The commission decided to adopt the latter course; and restrict the hight of main cornice, and the general style of all the buildings on the plaza, leaving those in other parts of the grounds more to individual fancy. Many of the great Expositions held in the world's history, have had their buildings designed, and architects selected by competition. We know what the results have been. Let us therefore not dispute the method of selecting the men, or the conditions it was thought best to impose, but rather, remember that the method of selecting without competition is almost if not quite new, and it is, therefore of great interest to us to compare carefully the buildings and grounds with those of past fairs, and see which method produces the most impressive and satisfactory results.

I quote once more from the honorable member of the French society on the subject of the use of stucco and the elaborate but scholarly ornamentation. "The American architects appear even to have forgotten the corelation, the intimate harmony which ought perforce to exist between the styles of decoration, and the materials employed. They appear not to have taken into account that one cannot make a work of art by copying in brick and iron the pure contours of Greek temples, which were built with blocks of white marble etc." Here is a serious point of critical attack. Such critics would lay down the formula for guidance in designing the Fair buildings, that only those forms of decoration should be employed which can be worked out in the natural materials with which they have been associated. We recognize the principle of adaptability of material to design; but would have such critics note that their beauty is without lasting qualities. Although the flower of the field is beautiful, it fades; the human figure is beautiful, yet its beauty is not lasting —the transforming of it into marble does not add to it. Beauty that is not lasting has its distinct place in the world. I would not seem to be advocating the sacrifice of stability, for superficial effects, as a general proposition; neither would I wish to see the designers of the Fair buildings so tied down as to be allowed to use only those forms which should be worked out in the natural materials commonly associated with them. To so restrict them would have been to debar

the most of the very best forms of ornament, for, the money expended being limited, and the buildings all being arranged to be torn down in six months: it is evident that the decorative portions *could not* have been based on the construction, and have been possible, under the circumstances.

The commissioners boldly decided to depart from beaten paths, and make the exterior a grand study in design, which in form, at least, should be worthy the exalted idea aimed at. Shall we not say that this was a wise decision? Endurance and stability is lacking in the exterior treatment: yet the eye is not conscious of any diminution of majesty and beauty thereby. The directors of the Fair had in mind to present to the public—as Mr. Van Brunt, one of the designers of the Mines building says,—the noblest conceptions of architecture as recognized by the world's experts. Let us accept this hypothesis as to what was consistent and proper to attempt under the circumstances, and then criticise the results.

Some critics, especially foreign, are fond of deploring the fact that the designing has been so much in the line of the established schools of the past. They would ask that the Fair buildings be studies in "the American style." I noticed that, since the early settlement of this country, not much in the line of a new style has developed in any of the European countries. About 1750 it was discovered that designers had gone around the circle substantially, and that all that was practically left, was to combine what was then known, and adapt it to the needs of the time.

Although foreigners have tried to broaden the fundamental types of architecture, and have failed even more signally than we; for we did make a brave attempt in Mr. Richardson's Romanesque, yet they never cease to delight to urge us to do that in which they themselves failed. It may be malice which thus leads them to invite us to our own destruction; but however that is, the architects of the Fair have not gratified them in this direction. "Scholarly work" has been the war cry, and the only "new styles" which will be exhibited to our foreign brethern will be conservative adaptations of the established styles, including Romanesque. Our critical eyes, therefore, will have fine scope. To follow the results of a dozen or more of the best architects of our country, and note their treatment and caution, yet withal boldness, in the handling of their immense problems and in their care and consideration of each others work and with reference to ensemble will be an intensely interesting study and *are* calculated to raise the tone of architecture in the entire country.

Another important feature connected with the Exposition will be the use of statuary designed as a part of the buildings. We have seen in this country a great deal of statuary of doubtful merit which has

been doubly so because of the little attention paid to its setting. Statuary is a most valuable addition to architecture; and in a sense architecture is very essential to a proper appreciation of statuary. That statuary which finds a natural resting place in a building architecturally perfect is rendered complete. Yet we have very few examples of the perfect combination of architecture and sculpture, those two grand divisions of art which should go hand in hand. The best sculptors of the land have prepared models, and the best architects have conceived the proper position for the statuary. We may well hope great things from the union. and as we roam about from building to building we should drink deeply from the well so full of the best that can be offered, and be thankful that so much has been expended in such a grand cause.

One other thought and I shall leave the subject for your further development. Great preparations are being made to show what can be done in the line of exterior color treatment in this country. As a rule, northern people have not vivid and harmonious conceptions of external color such as is common in southern Europe. We are the losers thereby. Color is one of God's greatest gifts to man, yet red and gray prevail in our large structures. While the main buildings of the Grand Plaza are to be of a uniform tint, the open loggias and entrances are to be elaborately colored in frescoes. Nothing is so easy to criticise as color effects; yet the perfect color harmony fills the soul more completely than almost any other conception which comes to man. Exterior color combinations are so rare in this country that I question the ability of the ordinary observer to justly criticise the results which will be observed at the Exposition. We should therefore be cautious in our criticism in this direction, and remember that even as a scarf which may be perfect harmony may not suit one persons fancy, yet it will probably completely satisfy another of equally good taste. So an entrance may be in itself a work of true art, and yet not please every individual or fulfill his own ideals of color.

Certainly I believe the World's Fair will have accomplished one great feat in the realm of art: if it can so cultivate a discriminating sense of and love for color. I therefore long for the time to come when my own desires shall be realized in this direction, and I shall be able to follow for a few days the conceptions of those who have in America few peers in the realm of color treatments; when in the splendors of the Golden Gate, as the center entrance of the Transportation building is called, I shall be able to fill my soul with that perfect harmony which I hope has been truly described as one of the most beautiful color creations of modern times.

DISCUSSION.

Mr. Searles:—The thought strikes me that the paper has a tone of apology, as though the buildings should be rather tenderly treated, and we must make allowance for conditions. There is a reason in that, certainly, but, after all, my notion is that when we go to see the buildings in their perfection, we shall say like unto the old wise man, or, rather, the lady that visited him, "Lo, the half has not been told me." We have any amount of pictorial views of the grounds and buildings; but in none of them do we get a comprehension of their size. We look upon them as ordinary buildings, and criticise them in the views and prints as we would any ordinary buildings; and if any human figures are shown in the views, we consider them mere pygmies, for they are mere specks in the views; whereas, if we should look first at the human figure till our eyes become accustomed to that scale, we then would begin to comprehend something of the dimensions of the structure. Now that such large buildings have been designed and finished in such manner as to preserve beautiful symmetry and proportion, argues great skill on the part of the designers.

The arrangement of the grounds and the water, about the buildings is very happy indeed. My impressions last summer were that in scope and design we have something in America which exceeds anything that has ever gone before in the way of public exhibitions, and no one can afford to lose the opportunity of going to the Columbian Exposition. The admission fee is a very cheap one if it were only to see the grounds and buildings, if one did not go inside of a single building. The lesson taught to the observer, the impressions received, will certainly be lasting; and while we know that the several exhibits cover the whole ground of modern civil advance, nevertheless, there is enough outside in the architecture, and in the statuary, and in the landscape ornamentation of the grounds, to pay one for going to Chicago. Those who have not seen it are chary about expressing an opinion, but some of our architect members are present and I hope they will, at least, give us some additional remarks before we discuss a separate question.

Mr. Herman:—I take exceptions to the criticism of the French architect in criticising the material and ornamentation of these buildings. If we consider the purpose for which these buildings were erected,—simply the purpose of housing a big show, temporarily,—I think the builders and architects were perfectly justified to use any material that they could press into service to represent anything that would enhance the beauty of the buildings. If we go to a theatre, we don't expect to see a castle on the stage built of granite. It simply gives that representation which a little imagination helps to be satisfied.

As to assisting the memory, may I be allowed to suggest something.

My practice has been, whenever I have been at a great exhibition, not to take very much time. I pass through very rapidly, but I take whatever reading matter I can take in connection with what interests me, and read it afterwards; and I have quite a collection of pamphlets and circulars of the expositions I have attended, and find this greatly assists the memory in remembering what I have seen.

MR. HOPKINSON:—Replying to Mr. Searles' remark I had no idea of apology at all. I thing the architecturai effort at the World's Fair is the grandest ever witnessed in the world, not excepting that of the time of Rome and the Cæsars. My paper was simply a cautionary effort that we might bear in mind some of the things which have been in the way of those who have tried to make the Fair great. I believe the Fair will be great, but I think it might have been greater. I think there are other sites more imposing, more grand. I think those who went to the Centennial and saw such a different aspect, will be disappointed in looking upon simply immense buildings. The planting of trees inside of a year and a half, to match such buildings, is child's play. It could not be done. They must depend on violets, and chrysanthemums, and roses, to enhance the scene. I think many will go and say, "This is gaudy in color, and that is hideous and out of proportion," and nothing will be so large and fine but they will undertake to criticise it. I think people should rather go there with a great deal of respect for what they expect to see, and with an understanding of the site and the general conditions which governed the problem and then, I think, as specialists in our line, we will agree. I do not wish to apologize for the Fair in any sense.

MR. SEARLES:—Replying to Mr. Hopkinson, I did not quite finish what I meant to say. I understood the author did not intend an apology for the buildings, but the thought occurred to me during the reading of the paper, that it might so be taken by some.

MR. COBURN:—It was my privilege to see these bnildings late in the fall last year, and I have nothing to say in criticism of any of the buildings or of the grounds. What astonished me, was the remarkable amount of landscape effect that had been produced. The buildings were in white then. As I remember them, so fine in their whiteness, I am sorry to hear they have been colored, they were not entirely white; a sort of creamy white, and I could not see how they could be any finer or better, even in their unfinished condition. I believe there never has been on this earth, a collection of buildings that could compare with them all in architectural effect. I do not think there is a spot on earth that can compare with that place at Chicago in architectural effect. As to the material not being what it represents, that is almost necessary in a temporary structure. We all recognize as one of the first principles of true art, that a material must be just what it is

represented to be, and that it should do the work it is represented to do. The perfection of Grecian architecture is due to this principle. And so it was in gothic particularly the French gothic. The material was used just as it should be, and where it had a purpose. The utility of the material was everywhere apparent. We know that the most beautiful line we see in a suspension bridge, is the long curve that seems to fulfill the constructive conditions. I have seen a copy of the coloring of the Transportation Building, and that leaves nothing to be desired in the way of coloring.

Mr. Wm. S. Gorton:—Speaking of Greek architecture, Mr. Coburn said that the lines of the buildings follow naturally from the material used. Then he used the same language with reference to a suspension bridge. Why don't we have a building in these times, in which the best form follows out from iron in the same way? If we can construct a building of stone, and these things come naturally, let us have a building constructed from iron and follow out the same principle, if it is natural.

Mr. Coburn:—It is just because we are not strong enough. But that is to where I expect the architect will grow sometime. When the architect is engineer enough, and the engineer is architect enough, then a building will represent exactly the material which it should, and the lines will be satisfactory to the eye, and they will be artistic and proper for the use to which they are put.

Mr. Herman:—As regards the new style of engineering in forming lines of strength, or rather, of resistance to load, the engineer has the best school when he goes to nature and observes vegetation; powerful trees as they grow up resisting wind pressure and developing in response to the strain. When engineers used cast iron, they were, to a certain extent, able to imitate these lines; but since steel has taken the place of cast iron entirely, I think if any engineer has any appreciation for the beautiful, he finds himself very much lost when he attempts to put mathematical formulas into practical use in trying to effect anything.

Mr. Hopkinson:—Some of the most beautiful forms ever conceived, have been entirely constructive forms. But I cannot see how we can lay down, as a guiding star ahead of us, that we should hold simply to constructive form and call that architecture entire. It is architecture, but there is something besides in architecture as a whole. It is made up of two elements—constructive form and ornament properly speaking. As time goes on doubtless the relation beween constructive form and ornament will be closer; yet I do not look to the theoretically perfect using of the two; for many standard forms did not develope in this way and cannot be other than thrown out of use if the strict and proper relation of constructive form to ornament is insisted on. We

must have the pilasters whether they are perfectly honest or not: and they will not always adapt themselves to our use.

Mr. Osborn:—Mr. Coburn says when the architect is more of an engineer, and the engineer more of an architect, they will arrive at perfection. In these days when the architect has to cover so much, and the engineer has to cover so much, the field is too broad for the architect to cover both. He has enough to do to be an expert in one line. I think architects and engineers ought to work together more: the architect should consult the engineer more freely, and the engineer should consult the architect more freely. The engineer makes architectural mistakes, and the architect makes engineering mistakes. If they would walk hand in hand in their work, they would avoid many mistakes. I saw something the other day in a church which illustrates this: there was an arch, and on top of that a Howe Truss resting the full length of the arch. (Illustrates.)

Prof. Benjamin:—The only way I ever had anything to do with architecture was in machine design. If the material is arranged in the line of stress, and is properly distributed, the shape of the piece will be pleasing. And if a structure is designed in that way, it will be more beautiful than if any attempt is made at decoration. The earliest designs were in wood; and the cast iron designs following, imitated wood and stone. and it was supposed to be the proper thing at the time. If you contrast that with the machine structures of the present day, where proper curves are used, and the material is distributed where needed, either in straight lines or curves, artistically, without regard to engineering knowledge, you will be pleased to see the result, and say that what is useful is beautiful.

Mr. Searles:—One thought more in regard to the Exposition. While it is true that a good many distinguished architects were invited to plan the buildings, yet, after they were finished, the coloring of them was left entirely to one man, so that there might be harmony in the grounds, in that respect, whatever differences there may be in the architecture. The matter was considered of so much importance that it was left to the care of an eminent artist in color: and I presume that if we are pleased with the result, it will be owing to the wisdom of that procedure, and the happy choice that was made by the Commission in the appointment of Mr. Millet.

Mr. C. O. Palmer:—Being an engineer primarily, and knowing but little of architecture, I have an idea that a thing is beautiful when it shows that the designer has solved the problem: that is, if we can see that he has tried to do something that is useful, and that he has done it in an economical way, and, at the same time, shows that it fulfills all the functions of economy and utility as well.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

THE CIVIL ENGINEERS' CLUB OF CLEVELAND.

June 13, 1893. Meeting called to order at 7:50 by the President. 30 members and visitors present.

The records of meeting of May 9th. were read and approved.

The application of Harold P. Dyer for active membership was read and Henry D. Marble and Wm. D. Kearfott, were elected associate members.

A brief verbal report of progress was made by Mr. Searles in behalf of the Local Committee on World's Columbian Exposition. A similar report was made by Mr. Porter on behalf of the committee on New Quarters. It was moved and carried that the President appoint a committee of six to make arrangements for the annual picnic. The President appointed the following: John L. Culley, chairman; and James Ritchie, W. P. Dittoe, J. N. Richardson, C. P. Leland and H. B. Strong. Mr. James Ritchie then read a paper on "Preliminary Surveys for a railroad line," which was discussed by Messrs. John Eisenmann, John L. Culley, Hosea Paul, W. H. Searles, H. C. Thompson and Jay F. Brown.

Adjourned, at 10 p. m. Frank C. Osborn, Secretary.

July 11th, 1893. Meeting called to order at 7:50 by the President. 17 members and visitors present. The record of meeting of June 13 was read, and approved. Ballots were canvassed for Mr. Harold P. Dyer, candidate for active membership, and he was declared elected.

Mr. W. H. Searles reported on behalf of the local committee on Columbian Exposition that the souvenir book had been prepared, and exhibited a sample copy. The Committee will forward a number of these books to Chicago and copies will also be mailed to members of the Club.

Mr. Porter reported that nothing definite had been accomplished in regard to new quarters and that probably nothing will be done this season.

A letter was read from Mr. John L. Culley, chairman of the Picnic Committee, to the effect that it was not desirable or practicable to hold a picnic this year and that therefore no arrangements had been made. After some discussion it was moved and carried that the Club accept and adopt the report of the Committee.

It was moved and carried that the Club dispense with the August meeting.

Mr. E. P. Roberts then read the paper of the evening entitled "Preliminary Surveys for Electric Light Stations." The paper was discussed by Messrs. Ludwig Herman, Prof. J. W. Langley, Prof. A. A. Skeels, Pres. A. H. Porter and C. O. Palmer.

Adjourned, 9:30 p. m. Frank C. Osborn, Secretary.

BOSTON SOCIETY OF CIVIL ENGINEERS.

MAY 17, 1893. A regular meeting of the Society was held at its rooms, 36 Bromfield street, Boston, at 7:50 o'clock p. m. President Freeman in thec hair. Fifty-nine members and fourteen visitors present.

The record of the last meeting was read and approved.

Messrs. William M. Brown, Jr.. Levi R. Greene, Herman Gregg, William P. Morse and James H. Stubbs were elected members of the Society.

The President called attention to the death of Augustus W. Locke, a member of the Society, which occurred very suddenly at North Adams, May 13, 1893, and suggested that the Society should be represented by a committee at the funeral. On motion the President was requested to appoint such a committee. The committee selected consisted of G. A. Kimball, J. W. Ellis and C. A. Allen.

The President was also authorized to appoint a committee to prepare a memoir of Mr. Locke, and named the same committee.

The Secretary was instructed to convey the thanks of the Society to Mr. George S. Morison for the interesting and instructive address given at the last meeting. The thanks of the Society were also extended to the General Electric Co. of Lynn, for courtesies shown the members on the occasion of the visit to the works of the company at Lynn.

Mr. Dexter Brackett gave an account of the freezing of the mains supplying water to Long Island which were laid in the mud of the harbor.

Mr. George A. Kimball opened the discussion of the evening on the "Measurement and Value of Water Power." The discussion was continued by Messrs. C. T. Main, L. M. Hastings, W. E. Buck and R. A. Hale.

On motion of Mr. Noyes it was voted to continue the discussion at the June Meeting.

Adjourned. S. E. TINKHAM, Secretary.

WESTERN SOCIETY OF ENGINEERS.

303RD MEETING, MAY 3, 1893. The 303rd meeting of the Society took the form of a dinner to Mr. James Dredge, British Royal Commissioner to the World's Columbian Exposition, which was held at the Grand Pacific Hotel on the evening of May 3rd. Over one hundred members and guests were present.

The proceedings opened at 7 p. m. with an informal reception in the parlors of the hotel, and at 7:30 the members and guests proceeded to the banquet room. Before serving dinner, President Robt. W. Hunt called upon the Secretary for the report of the Board of Directors meeting, from which was announced the following:

Members elected: Messrs. A. M. Burt, Peter Mogensen, F. L. Easley, Jas. E. Maloney, W. A. Aiken, H. L. Hollis and John C. Beye.

Applications were received and filed from J. H. Lary, H. A. Miller, John W. Cloud, Wm. Forsyth.

The dinner which appeared to be a complete success was followed by speeches from President Hunt, the guest of the evening, Mr. Dredge, Col. H. G. Prout and Messrs. O. Chanute, D. J. Whittemore, J. F. Wallace, Jas. F. Lewis and D. C. Cregier.

304TH MEETING. JUNE 7TH, 1893. The 304th meeting of the Society was held at the "Engineering Headquarters," 10 Van Buren Street, on Wednesday, June 7th, 1893, at 8 p. m. President Robert W. Hunt in the chair and thirty-five members and guests present.

The reading of the minutes of the last meeting was dispensed with.

The following was reported from the meeting of the Board of Directors by the Secretary:

Members elected: Messrs. John W. Cloud, Wm. Forsyth, H. A. Miller and John T. O'Brian.

Applications received and placed on file: Messrs. Geo. W. Chandler, John H. Brown, F. L. Clerc.

There being no further business the paper of the evening, "The Chicago Railway Problem," being a continuation of the discussion on this important subject, was read by the author, Mr. Thos. Appleton.

The paper was followed by remarks from Mr. L. E. Cooley and Mr. Wm. E. Williams. It will be printed in full in the JOURNAL OF THE ASSOCIATION as soon as possible.

The meeting then adjourned. The rooms of the Engineering Headquarters being open the opportunity was seized to enjoy their hospitality.

JOHN W. WESTON, Secretary.

ENGINEERS' CLUB OF ST. LOUIS.

384TH. MEETING, JUNE 7. 1893. The club met at 8 p. m. at the club rooms, President Moore in the chair, and twenty-two members and two visitors present.

The minutes of the 383d meeting were read and approved.

The executive committee reported their action at the 145th meeting.

Mr. Frank B. Maltby was proposed for membership.

In the absence of Prof. Howe, Mr. Ed. Flad read the paper of the evening on "The Hinged Suspension Bridge." The paper gave the full methods and diagrams for making all the calculations in suspension bridges.

Discussion followed by Messrs. Gayler, Flad, Ockerson, Moore, Seddon and Russell.

Mr. Crow presented an interesting description of a dry kiln heated by steam which had caught fire at the top of the roof. Discussion followed by Messrs. Seddon, Ayer, Flad, Moore, Kinealy, Bryan, Judson and Perkins.

Adjourned. ARTHUR THACHER, Secretary.

MONTANA SOCIETY OF CIVIL ENGINEERS.

JUNE 10TH., 1893. The regular monthly meeting of the Montana Society of Civil Engineers was held at the office of Messrs. Sizer & Keerl in the Atlas Building on Saturday evening, June 10th, 1893, at 8 o'clock p. m.

Present: Messrs. Haven, Cumming, Herron, Wheeler, Hovey, McNeil, Foss and two visitors. Minutes of last meeting were read and approved. Application of M. E. Reed for membership was favorably reported on by the Trustees and the Secretary was instructed to send out letter ballots. Henry C. Relf was duly elected to membership in the Society.

Messrs. Cumming, McRae and Foss were appointed a committee to see if any arrangements could be made with the heirs of Col. W. W. DeLacey,

late President of the Society, by which his library of Engineering works could be secured by the Society.

A resolution was also passed calling upon the committee appointed to prepare a memorial of Col. DeLacey's life to report to the Society at an early date.

The Society then proceeded to discuss the question of manufacturing industries in Montana. Mr. Cumming stated that the barley straw raised in the Gallatin Valley was particularly adapted to the manufacture of paper, and it was understood that a paper mill was soon to be erected at Manhattan. At present most of the straw raised by the Manhattan Company is burned. Mr. Foss enquired if flax had ever been raised in the Gallatin Valley, and Mr. Cumming stated that it had and that it grew wild in some portions of the valley. He could see no reason why a linseed oil factory could not be made a commercial success.

The manufacture of sugar from the sugar beet was also mentioned as a probable industry of the future. Mr. Herron stated that large deposits of iron ore existed in the vicinity of Great Falls, and other deposits were mentioned by different members. Mr. McNeil said that he understood the chief difficulty to be encountered in manufacturing pig iron in Montana was the quality of coal required for furnace use. If Montana coal could be successfully used in blast furnaces there was no reason why Montana should not produce iron and numerous allied industries be established.

Mr. Cumming thought that lead pipe and shot should be manufactured here. The smelting works produce large quantities of silver lead bullion; there seems to be no good reason why the bullion should not be refined here and the lead used in some manufactory. After a further discussion on the electrical transmission of power, and a need of a further development of the agricultural resources of the State, the Society adjourned.

G. O. Foss, Secretary.

WISCONSIN POLYTECHNIC SOCIETY.

18TH MEETING. MAY 8, 1893. Meeting called to order at 8:20 p. m. at the Davidson Hotel. Nine members present. After the reading and acceptance of the minutes the President called for the particular business of the meeting. Mr. Goodhue spoke of the important meetings of various engineering societies both here and in Chicago during the summer and proposed the appointment of a committee to formulate some plan in regard to entertainment of visiting engineers. Mr. Goodhue, Mr. Benzenberg and Mr. Cowdery were appointed on this committee.

Mr. Goodhue reported for committee on quarters that Mr. Dorman had offered free use of a room at Davidson's Hotel for the society's meetings. Mr. Russell moved that the thanks of the Society be tendered the management of the hotel and offer be accepted. Carried.

Secretary presented a bill for quarterly dues and on motion it was referred to the Executive Committee.

President Barr brought up the subject of increasing the interest in the regular meetings.

It was suggested that committees be appointed to bring subjects for discussion before the Society. After considerable debate it was decided that any member of the Society when meeting with anything difficult or peculiar in their experiments or routine work should report same to the Society.

Mr. Schinke was asked to report at next meeting on the electrolysis of cast iron pipe recently taken out of service in city water mains.

Secretary reported receipt of Mr. Knudsen's work on Triangular Surveys (from Single Station, and Mr. Goodhue was appointed to report on same next meeting.

Mr. Goodhue here gave a very interesting description of the Ashland monolith and the methods which might be used in transporting the huge stone to Milwaukee.

The opinion prevailed among the members that it would be extremely difficult to move the stone in its present condition, being green and completely saturated with water. It should be thoroughly seasoned before attempting to move it.

Adjourned. W. S. Mason, Secretary.

19th. Meeting, June 12, 1893. Meeting called to order at 8:30 p. m. at the Davidson Hotel. Vice-President Goodhue in the chair. Minutes of the previous meeting were read and approved.

Mr. Goodhue as Chairman of the committee to propose some method of entertainment of visiting engineers during the summer, reported progress.

Mr. Schinke, Asst. City Engr., under the title of Electrolysis of Gas and Water Mains, gave some interesting descriptions and valuable information in regard to the decomposition of underground pipe in close proximity to electric street railway tracks and showed the electrolysis action in a number of samples of pieces of pipe recently taken out of service.

Mr. Benzenberg gave further interesting data and said that a quantity of soil was taken from the immediate vicinity of the pipe and given to a chemist who gave as his opinion that decomposition was due almost entirely to induction.

In Boston, Cleveland, Indianapolis and other cities where electric railways are numerous, the same trouble has been experienccd. Without doubt the serious defect lies in the imperfect conductor for return current. Many electric lines return the current by way of the rails, others by a return wire. When by reason of rust or imperfect connections, the resistance being greatly increased and the current seeking the route of least resistance is often returned by way of the water mains. The decomposition seems to take place at the point where the current leaves the mains. The iron soon becomes of a very soft and spongy nature and very soon gives way. The easiest solution of the problem seems to be to make a good connection between water main and generator in power house.

On the Becker line in this city a number of rails are connected with the fire hydrants and if thorough connections are made no objections can be raised. It is the intention in future where return wire cannot return full current to make proper connection between water pipe and generator.

Several street railway companies have recently laid very heavy copper cable between rails for return current and still a loss of from 10 to 12 per cent. is found. Where the return is made by way of rails there is a loss of between 25 and 35 per cent.

Mr. Birkholz here presented his paper on the management of modern steam plants, short discussion followed on the advantages of various furnaces. Several objections were raised against the Hawley furnace, chief among which were that the flues were liable to stoppage and a consider-

able draught was required. The Murphy furnace is being used quite extensively in Chicago and giving very good results.

Prof. Speirs of the Peoples' Institute, being introduced by Vice-President Goodhue, explained the objects of the Institute and of its desire to establish an industrial school for young mechanics.

Mr. Benzenberg moved that the Vice-President and Secretary draw up suitable resolutions giving hearty approval of the movement.

The following resolution was presented:

Resolved—"That the Wisconsin Polytechnic Society heartily endorses the establishment of industrial classes in connection with the Peoples' Institute, and desires that the Society be represented on its board of managers."

Motion was made and carried that the President be empowered to appoint a representative on the board of managers.

Nothing further being presented the members adjourned to an adjoining room where light refreshments were served and the time and place of the annual outing was discussed.

W. S. MASON, Secretary.

ASSOCIATION OF ENGINEERING SOCIETIES.

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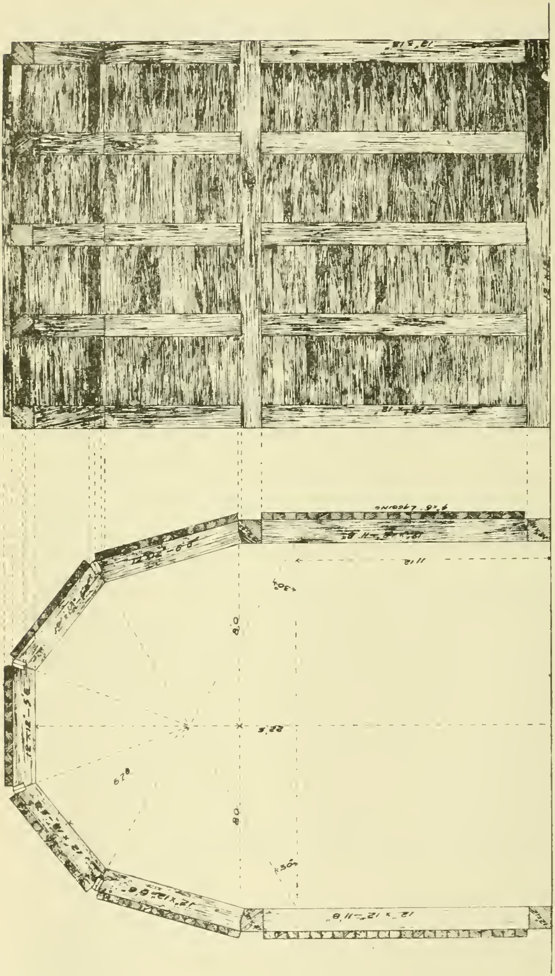
LINING OF BOULDER (WICKES) TUNNEL.

By E. R. McNeill, Asst. Engineer, in Charge of Construction, Member Montana Society of Civil Engineers.

[Read January 14, 1893.]

History. In bringing the subject of this paper before you I think it will be necessary to give some information as to the history of the Boulder (Wickes) tunnel. The tunnel, as most of you probably know, is situated about midway between Helena and Butte on the Montana Central Railway, and pierces a spur of the main range of the Rockies. This spur is, I believe, called the Boulder range from which the tunnel takes its name. The summit on the line of tunnel reaches an altitude of 6230 feet above sea-level, and the summit of grade an elevation of 5454 feet above sea-level. The tunnel is 6112 feet in length and the summit of grade is 4000 feet from the North portal. The alignment is tangent with the exception of 150 feet of 30 minute curve at the North end which was put in as an easement curve to an 8 degree which extends to the tunnel portal. The line of tunnel was located during the late fall of 1886 and the early spring following. Active construction work was begun at the South approach April 7, 1887 and the tunnel proper at the North end April 23, and South end May 6, 1887. The work progressed without interruption until September 12, 1888 when the headings met.

Formation. The material encountered in driving this tunnel was of two varieties, viz: From the North end for a distance of 4950 feet the formation is a blue trap rock interspersed with seams of talc which vary in thickness from a fraction of an inch to several inches. The re-



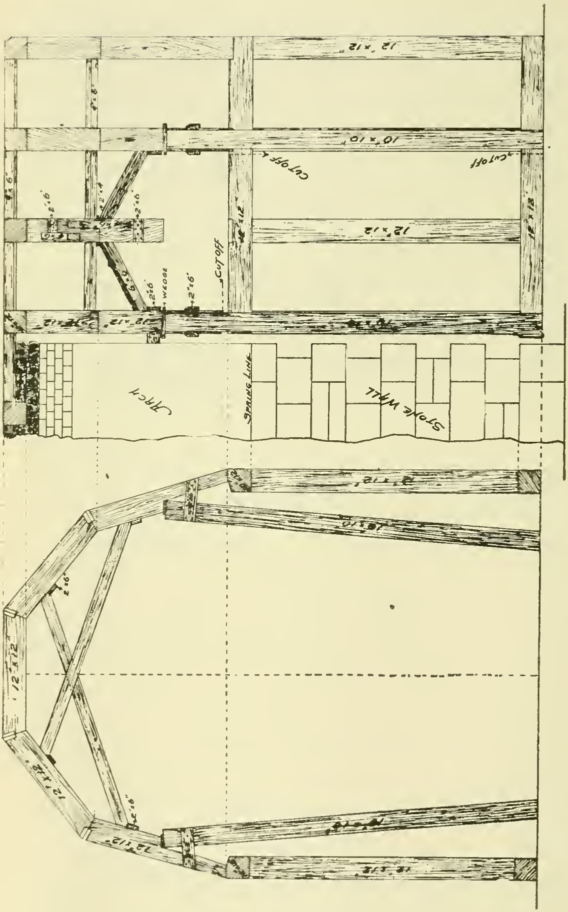
SECTION

LONGITUDINAL SECTION

PLATE I.—Plan of Original Tunnel Timbering.

maining 1160 feet is a syenite formation which is sometimes miscalled granite. This formation consists of a mass of boulders varying in size and the intervening spaces are filled with disintegrated material of the same sort. Owing to the absence of uniformity in either the trap rock or syenite formation it was found necessary to timber the tunnel throughout. The trap rock seems to have been affected very much upon exposure to the air, and as a result has caused considerable damage to the timbering due to the swelling of the ground; but the syenite formation has allowed the timbering to remain intact. So much for the history of the tunnel up to the time the lining was begun. In September 1891 the contract was let for lining the tunnel with masonry, as it was thought expedient to begin this work before the timbering had been weakened by decay. Active work on the masonry was begun in January and the first stone laid Jan. 9, 1892. The form of masonry adopted by Mr. E. H. Beckler, Chief Eng., consists of a coursed rubble wall of granite, extending from sub-grade of tunnel a height of 13 feet 8 inches to springing line of arch, and generally a thickness of 20 inches without batter on the face. The arch is a full center circular arch and consists generally of four rings of brick layed in rowlock form. In the progress of the work it has been found necessary to vary these dimensions. When greater strength was needed we have put in as heavy as 30 inch walls and six rings of brick. The width of tunnel between side walls is 15 feet 8 inches and the radius of arch 7 feet 10 inches, making the height from sub-grade to intrados at crown of arch 21 feet 6 inches and deducting 2 feet for ballast, tie and rail, gives 19 feet 6 inches head room, and 15 feet 8 inches width of tunnel. All masonry is laid in best quality of American cement mortar, in proportions of two parts of sand to one of cement by measure.

Material. The stone used in lining the tunnel is granite of a very good quality, which is taken from a quarry situated on the Boulder river, 2 miles above the town of Boulder and nine miles from the tunnel. The quarry face is 200 feet above the level of the spur tracking running by the foot of the bluff. The stone cutter's derricks, two in number, are situated at the track level and the stones are transported from the quarry bench to these derricks by means of an inclined tramway operated by gravity. A three rail track with turnout at the center being laid up the slope of the mountain upon which two small cars run, which are attached to the ends of wire rope. The rope passes around sheaves which can be regulated by a brake. The stones from the quarry are loaded on the small cars by a steam hoist derrick standing on the quarry bench. This derrick has a 50 foot boom and mast. At the delivery end of the tramway the two derricks are set so they can take the stones from the tram cars from opposite sides and after being cut place them on flat cars to be transported to the tunnel.



SECTION

LONGITUDINAL SECTION

PLATE II.—Details of Temporary Timbering for Removal of Side Timbers.

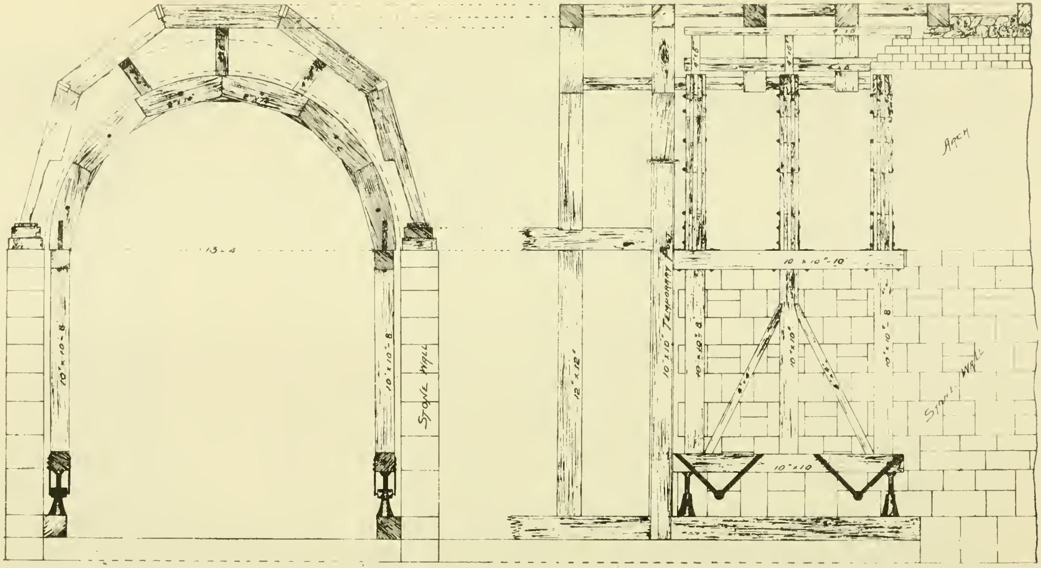
Both stone cutter's derricks are steam hoist with 50 foot boom and mast, so that the cutter's yard has a limit of one hundred by two hundred feet, and can accommodate forty cutters if necessary.

BRICK. The brick used in the arching are made in Helena and are the best selected hard brick available.

CEMENT. The cement used is Louisville which must give a tensile strength of at least 65 pounds per square inch after seven days in water. A thorough test of each car is made immediately upon its arrival at the tunnel. The series of tests which I have kept a record of might be a very interesting subject to dwell upon, but will only say here that of some twenty-five cars tested only one has failed to reach the required standard, while some have given as high as 125 pounds per square inch.

PLANS. The first plan adopted for the work contemplated the removal of all timbering and cordwood put in during the building of the tunnel.

(Plate VII shows two sections of this plan which give the relative positions of the masonry and timbering.) This plan was followed for about four months, bnt it was found that the work could not be done expeditiously, and at the same time always keep the tunnel free from falls and slides, which interfered with the passage of regular trains. In April 1892 a new plan was adopted by which the tunnel was lowered one foot. As the masonry section remained the same the object gained, was, in being able to leave the three roof segments with over-lying cordwood and debris undisturbed, and thus eliminating the greater part of the danger of falls and slides. (Plate VIII shows two sections of this plan which is now being followed successfully) In order to give you a fair idea of the manner of carrying on this work we will look for a moment at Plate I, showing cross section and longituditai section of the original timbering. The section consists of a five segment arch with wall plate, and sill. The key and two hip segments are the same length (being five feet 8 inches outside and 4 feet 11 inches inside, while the two crow feet segments are considerably longer ($6\frac{1}{2}$ feet outside and 6 feet 2 inches inside.) All timbers are $12'' \times 12''$. The posts are 11 feet and 8 inches long The exterior surface of the arch and sides is closely lagged with $4'' \times 6''$ lagging. The sets of timbering are generally 4 feet apart and therefore the lagging is put in four foot lengths. As the crow feet segments are longer than the hip segments and key segments, the form of the arch timbering is elliptical to a certain extent, so that the brick arch which is circular in form cuts the greater portion of the crow feet away and merely clears the hip and key segments (Plate III.) The width of tunnel between posts of original timbering is 16 feet and width between walls 15 feet and 8 inches, so that we have two inches to take from our tunnel on each side

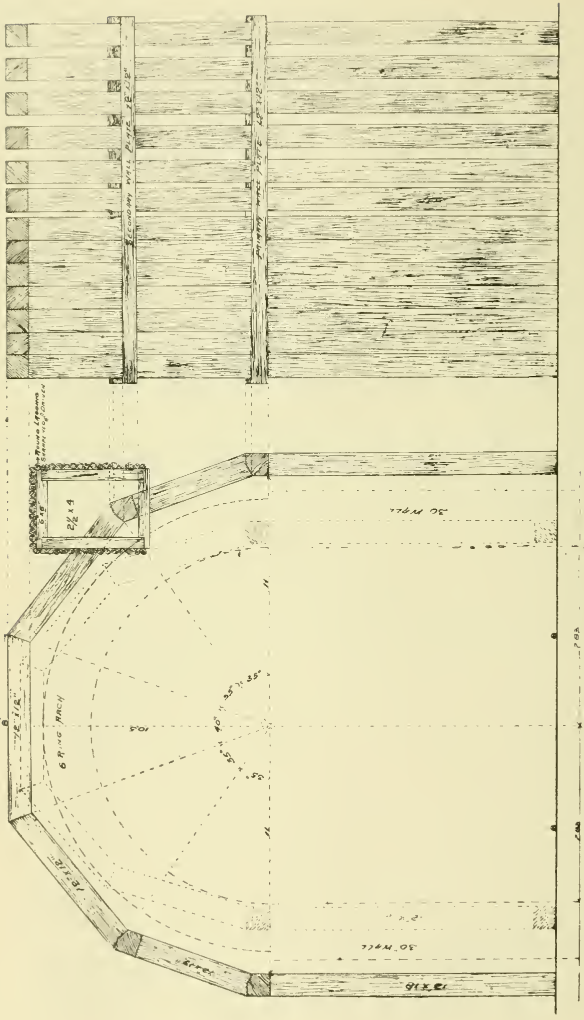


SECTION

LONGITUDINAL SECTION

PLATE III.—Details of Centering and Removal of Necessary Arch Timbers.

and 16 inches for posts and lagging and two inches space to occupy back of this with 20 inch wall. For our purpose in this paper we will only consider the plan now being followed. (Plate VIII.) In order to lay the side walls it is necessary to remove the wall plates, posts and sills of the section to be built. It has been found most convenient to build the side walls in 8 foot sections, carrying both sides of the tunnel along together. In order to remove the necessary timbers and at the same time to safely support the roof timbers, (Plate II, cross and longitudinal sections) the crow feet segments on both sides of two sets, which are 8 feet apart, are sawed at the middle about half-way into the stick, and the portion from the cut, down to wall plate, is split out so as to give a shoulder to brace the end of a temporary post against. This temporary post extends down to sub-grade, and at the bottom is just far enough from the rail for clearance of train, which allows it to have about one foot batter. These posts are securely wedged at the top and spiked fast to the crow feet segments by means of cleats. After these temporary posts are put in on both sides, 8 feet apart, it is then necessary to secure the intermediate set of arch timbers, the weight of which is carried by the temporary posts. As the set has no support directly under it, it is necessary to provide against down pressure and pressure from the sides. To provide against the first 6″ × 6″ struts (Long. Sec. Plate II) are put in which are cut with a bevel to extend from the crow feet at height of tops of temporary posts to the opposite sides of the intermediate crow foot at the top, and held in place by means of 2″ × 4″ and 2″ × 6″ cleats, spiked to the crow foot at top and bottom of struts. You will see that in this manner a truss is formed which will support the set with what may be over-lying it. As this truss takes the angle with the vertical which the crow foot does it can readily be seen that it will not resist side pressure, so to provide for this 4″ × 6″ braces (Plate II, cross section) are put in across the tunnel from near the center of this intermediate crow foot to the upper end of the hip segment opposite, and cut with bevel to fit and kept in place by means of 2″ × 6″ cleats. At the end of such 8 foot section which adjoins the masonry it is necessary to put in a 4″ × 6″ block from the crow foot to the arch which will prevent the crow foot kicking out through weight from the trussed set. The section of timber is now ready to be removed; this is accomplished by sawing off the trussed crow foot at, or near the center; the crow foot adjoining the masonry a few inches above the wall plate, and the wall plate and sill flush with the post farthest from the masonry. The loose rock is now removed and floor of tunnel lowered one foot for width of length of section, and we are ready for the stone. The stone work is all done from flat cars and placed in the wall by means of small hand derricks mounted upon a flat car. (Plate VI, end and side elevation.) These derricks, two



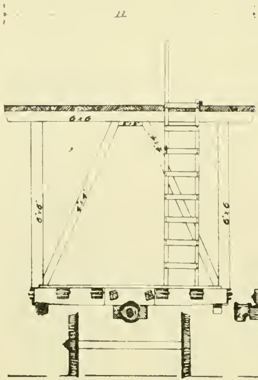
LONGITUDINAL SECTION

SECTION

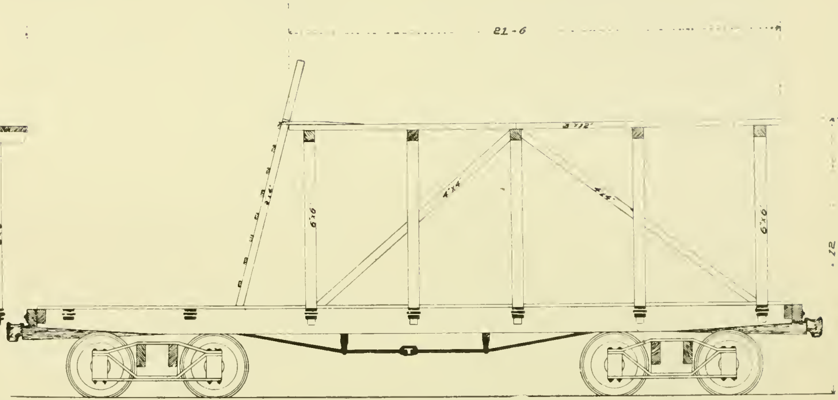
PLATE IV.—Plan of Timbering Slides and Falls.

in number, are mounted on opposite sides of the car and each attends to a side. The masts are 8″ × 8″ and 9 feet 3 inches and 10 feet 3 inches long, respectively. The difference in length being to allow the guy timbers (which extend from the top of each to opposite side of car) to pass over and under each other. These guy timbers are 6″ × 6″ and are securely fastened to the car by means of ½ inch strap iron shoes. The booms are 6″ × 6″ 12 feet long with strap iron extensions which carry 3 pulleys, two six inches and one five inches in diameter. The hoist is by means of single 10″ blocks with drum and crank while the boom is raised and lowered by means of double 6″ blocks and pulleys. The stones are loaded along both sides of the flat car, and thus leave a runway through the center along which 3″×12″ planks are laid and stones taken on a dolly from one car to another to the derricks. A car of coarse rubble is always attached to the train and all spaces between the back of the walls and original tunnel walls are compactly filled as the masonry is carried up. Having completed such an 8 foot section of side walls, we are now ready to prepare for the arching of same. The arch is built upon centering, the ribs of which are 5½ inches less in diameter than the distance between side walls so as to permit the use of 2¾ inch lagging. Each center (Plate III, cross and longitudinal section) has three ribs, made of one or two inch board segments, ten inches thick and 14 inches its greatest depth. These ribs are mounted on frames (which follow the opposite walls) and are 4 feet apart making about 9 feet total length of center from outside to outside of rib. The supporting frames consist of 3 posts 10″×10″ 8 ft. long with 10″×10″ cap and sill and 4″×4″ braces from foot of outside posts to near top of center post which is capped and bevelled to receive same. The ribs are secured to the frames by means of "*L*" pieces of strap iron on both sides of each which are securely bolted together and also bolted to the wall plate of frame. The center is carried on dollys which run on 12″ × 12″ sills well bedded at foot of wall. In order that the center can be run ahead to a new section of stone work, it is necessary to remove our temporary posts and cross braces. (Plate II.) Before removing the temporary posts the crow feet segments which they support, are blocked to the top of the wall. (Plate III cross section.) If the ground is treacherous the intermediate crow foot is also blocked to wall before the cross braces are removed, but generally this is not necessary for the short time required to move the centering and get additional support.

After removal of temporary posts and cross braces the center is run ahead on the dollys until in proper place, then raised by means of jacks until the top of wall plates supporting the ribs are flush with top of wall and carefully centered. This being done, it now remains to remove such timber as will interfere with the brick work, which con-



END ELEVATION

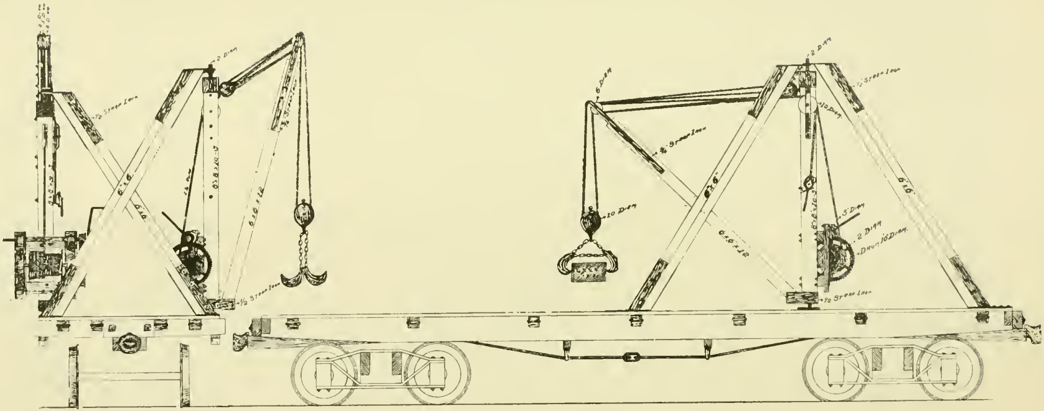


SIDE ELEVATION

PLATE V.—Brickmasons and Timbermen's Staging Car.

sists of what remains of the crow feet segments and the cordwood and lagging behind them. At the same time support must be found for the three segments which are not removed. These are supported by means of three 4″ × 6″ timbers which extend across the center of each of these segments in two sets of arch timbers, which will give the eight feet required. These 4″×6″ timbers are supported by means of short 4″×6″ posts which rest on the ribs of the centering. The crow feet segments can now be removed by knocking out the blocking and the section is ready for arching. The arch is built up from the springing line on both sides at the same time, and four masons are employed in doing the work. The rings are built beginning with the intrados, which is brought up, say a distance of about two feet, from springing line. great care being taken that the bond is perfect between all bricks in this ring. Then the back of the ring is well plastered with from $\frac{3}{8}$ to $\frac{1}{2}$ an inch of mortar and the second ring brought up to the same height and plastered on the back, and so on until the last ring is laid, when a coating of mortar is put on. After bringing the full width of arch up a distance of two feet new laggings are placed upon the ribs for an additional height of two feet, when the process is repeated. All space between the exterior surface of arch and roof of tunnel is compactly filled with dry rubble as the arch is brought up. When high enough so that the hip segments have a foot or more bearing on the masonry, (See Sections Plates III and VIII) the segments are securely wedged and blocked up against the brick work and the longitudinal 4″ × 6″ timbers removed. The remaining space is now clear for completion of the arch and both sides are brought up until there is not sufficient space for four masons to work, when the keying is completed by two masons, beginning at the completed end and working back toward the toothing end of section. The brick work is built from the top of a staging car (Plate V, side and end elevation.) The floor of this staging car is 12 feet above the top of rail and, therefore, about level with the top of wall plate of original timbering. The width is 11 feet; the posts and caps of staging are 6″ × 6″; the floor plank 3″ × 12″ and 4″ × 4″ braces, both cross and longitudinal, are put on to prevent swaying. Brick and mortar are carried up ladders to the top of this staging at opposite ends and the rubble is wheeled on an incline, (mounted on movable horses) from a coal car coupled next to staging. Brick masons work from floor of staging car until the arch is about one-half completed, when a higher staging is required. This consists of two horses supporting 3″ plank.

SLIDES. On Feb. 11th and July 30, 1892, slides occurred which in each case filled the tunnel for a distance of 16 feet, and as the ground was very treacherous, owing to water and large talc seams it was necessary to put in solid timbering throughout before the tunnel could be



END ELEVATION

SIDE ELEVATION

PLATE VI.—Stonemason's Derrick Car.

cleared of debris. Plate IV, cross and longitudinal sections shows the manner of timbering these slides. Owing to the nature of the ground it was deemed necessary to increase the strength of masonry and therefore 30″ walls and a 6 inch arch was made. The timbering put in had to be outside of this masonry section and in order to do this it was necessary to make the timber section 22 feet wide in the clear and 23 feet 2 inches high. Owing to the heavy pressure of the debris driven through and to the unusual width of section required, with only rise enough to the arch to merely clear the brick work at crow, it was important to give the timbering additional strength and stiffening. This was accomplished by using a secondary wall plate which is set in the same angle with the vertical that the lower crow foot segment makes, and the hip segments cut with crow foot to fit. The principal advantage gained by this secondary wall plate, besides strengthening the timbering, is that it was possible to drive the arch section as two headings instead of one, thus lessening the weight to be held up, by reducing the exposed area. The secondary wall plates were put in place by running small miners drifts on both sides through the full length of slide. The small drifts (Section, Plate IV) were driven by first driving sharpened lagging ahead for a distance of about four feet and the core of debris then removed, and square sets of 6″ × 6″ timbers with shoulders on cap and sill, were put in as material was taken out. When the sets had reached the points of the first lagging a new set was driven ahead a distance of four feet and the process repeated. It was necessary to keep the face of these small drifts well breast-boarded all the time. After these two side drifts had been run through the debris to solid material, the secondary wall plates were set with proper line, grade and cant and securely blocked in place. These wall plates were put in four foot lengths, with one foot lap and securely fastened together with boat spikes. Cross drifts were then run from these lateral drifts to meet at the center, and given sufficient upraise to accommodate the two hip and key segments. Each one of these cross drifts when connected would generally give space enough to allow two permanent sets to be put in. This process was repeated until the permanent timbering was complete throughout the length of the slide and down to level of secondary wall plate. The core from level of secondary wall plates to crown was then removed, and a heavy timber laid on debris longitudinally, upon which posts were placed which extended vertically to key segments, and at an angle against the hip segment, and relieved a portion of the weight to be supported when drifting began below the secondary wall plates. Work was then started at the four corners at the height of primary wall plate. Drifts were not necessary in placing primary wall plates and crow feet, but the wall side was carefully breast boarded. The longitudinal timber at center of debris, and posts

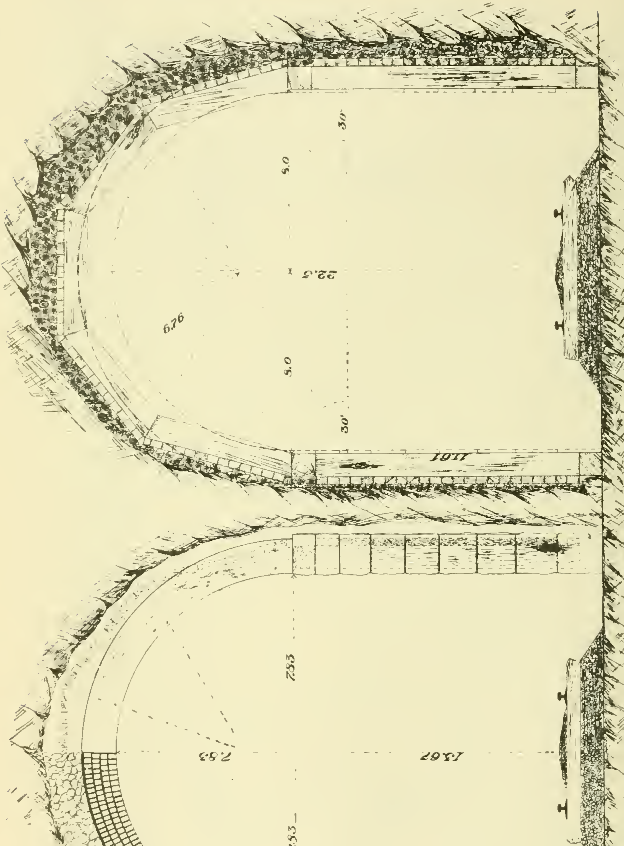


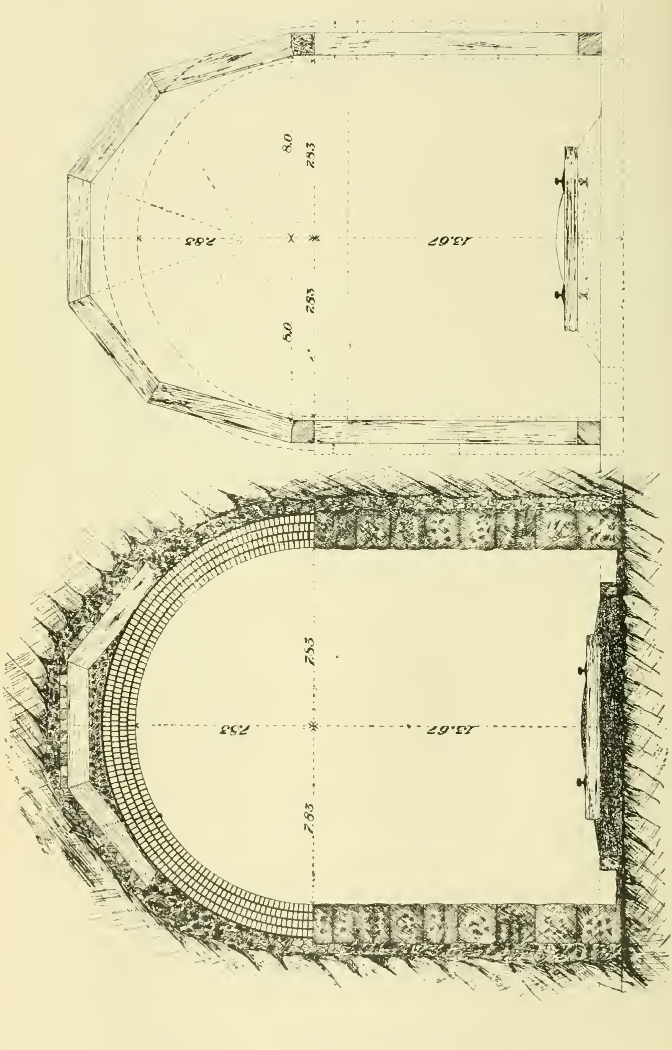
PLATE VII.—Plan of Masonry. Adopted October 24, 1891.

to key and hip segments were then removed and core taken out to level of primary wall plates. The bench was then taken down by degrees and arch held up by jacks, the posts being put in one at a time. After the posts were all in, the remaining debris was removed and side trench excavated, when the masonry was put in without further trouble.

RECESSES. Plate IX shows plan of handcar recess, two of which are to be built. They are situated about 2000 feet from either end of tunnel, so that in case a section crew is over-taken by a train they can reach a place of safety with their car within a distance of 2000 feet. The arch is a segment of 7 feet span with $^1/_6$ rise, and only the face is stone, the backing consists of four rings of brick. All stones at line of springing arch are skew backs. The side walls are 20 inches and back wall 16 inches and the depth of recess is 7 feet 6 inches in the clear. Longitudinal section Plate IX shows actual cross section of tunnel where one of these recesses has already been constructed. Plate X shows front elevation and longitudinal section of portals.

SPECIFICATIONS FOR PORTALS. Portal work will include 8 feet of stone arch extending into tunnel from portal face, parapet, and wing walls. The 8 feet of stone arch and walls will be second class bridge masonry and first class ring course. Side walls will be second class bridge masonry 20 inches thick laid in courses of uniform thickness and diminishing in thickness upwards. All stone will be dressed to uniform beds. Vertical joints will be dressed back for a distance of 8 inches from the face. All joints and beds will be $\frac{3}{8}$ of an inch thick. All stones to be pitch faced and accurately laid to line with a bond of not less than one foot. Corner stones will be fine pointed so that projections will not exceed one-eighth of an inch on face and exposed end. Arch will be 20 inches between intrados and extrados. The soffit of arch sheeting will be crandalled to $\frac{1}{4}$ inch points and all stones cut to exact size, for $\frac{3}{8}$ inch coursing, heading and radial joints. Ring course (except key) will have pean hammered or patent hammered soffit and face (not less than six cut.) The key will be pitch-faced with two inch margin draft. The ring stones will make bond with the spandrel walls. Coursing joints will be continuous and heading joints will make bond of not less than eight inches, and also be bonded into adjoining brick arch.

PARAPET. The belting course 10 inches rise will have crandalled face. The panel will be of one course two feet rise, pitch faced with two inch chisel draft. Coping sixteen inches rise with bush hammered face, top and exposed ends. All coping stones will be cut to neat size and be laid with one-fourth inch joints and beds. Belting and panel course will be dressed 12 inches back from face on vertical joints and laid with $\frac{3}{8}$ inch beds.



SECTION

SECTION

PLATE VIII.—Plan of Masonry. Adopted March 30, 1892.

WING WALLS. (See Plate X.) The back of the wall will be vertical and all courses will vary in width so as to be 20 inches under copings. The vertical batter will be one inch to the foot, and horizontal batter ½ inch to the foot. The rise of courses shall be the same as quoins so as to give bond with the spandrel walls. Vertical joints shall have bond of not less than one foot. All stones shall be pitch faced. Beds and joints must be dressed for a distance of not less than eight inches from the face. The coping, 8 inches thick, will be fine pointed (8 cut) on face, top and exposed end, and pitched on back and jointed ends. Spandrel stone will be same finish and character as wing walls.

SPECIFICATIONS FOR THE GENERAL MASONRY. (Plate VIII.) Side walls must be of coursed rubble stone masonry. The stone may be granite or sandstone, as approved by Chief Engineer. The stone masonry must extend from the base of side walls to springing line of arch. The courses must be built of stone not less than six inches rise except as further provided and may vary in thickness to two feet, in no case exceeding the latter rise. The stones which do not extend from front to back of wall shall not exceed one quarter of the whole volume of the wall, and shall be so arranged as to give good bond in work. The front, horizontal and vertical edges must be pitched to a line and no part of the face of said wall shall project more than one inch from said pitched line. The stone must be of such dimensions as to reach from front to back of wall. This may be changed however as to the rear corner, to the extent of leaving out one third of the rear face, of each individual stone. The rear corner thus constructed shall be filled with stone of proper thickness and as large as can be used. The intention being to use as few spalls in the work as possible. The beds and builds of the stone to be brought to such surface that the mortar joints at front face shall not exceed ⅝ of an inch. The builds to be vertical and at right angles to the surface for at least 8 inches. Care shall be taken that the whole shall be properly bonded and that the stone in the center courses shall break joints with the course below. All courses must be continuous throughout the tunnel. The top of the wall is to be brought to a true and even surface throughout its entire width on which to rest the brick arch. The exterior joints, both vertical and horizontal must be pointed with clear cement mortar.

BRICK MASONRY. All brick must be selected hard burnt and subject to the approval of the Chief Engineer. All mortar must be thoroughly mixed in small quantities and must be used quickly before incipient setting has commenced. All vertical joints must not exceed ¼ of an inch and must be compactly filled with mortar. The mortar joints between rings must not be less than ⅜ or to exceed ½ an inch, and particular care must be taken in laying one ring over another that the mortar is in proper condition to receive the same. Outside of the outer

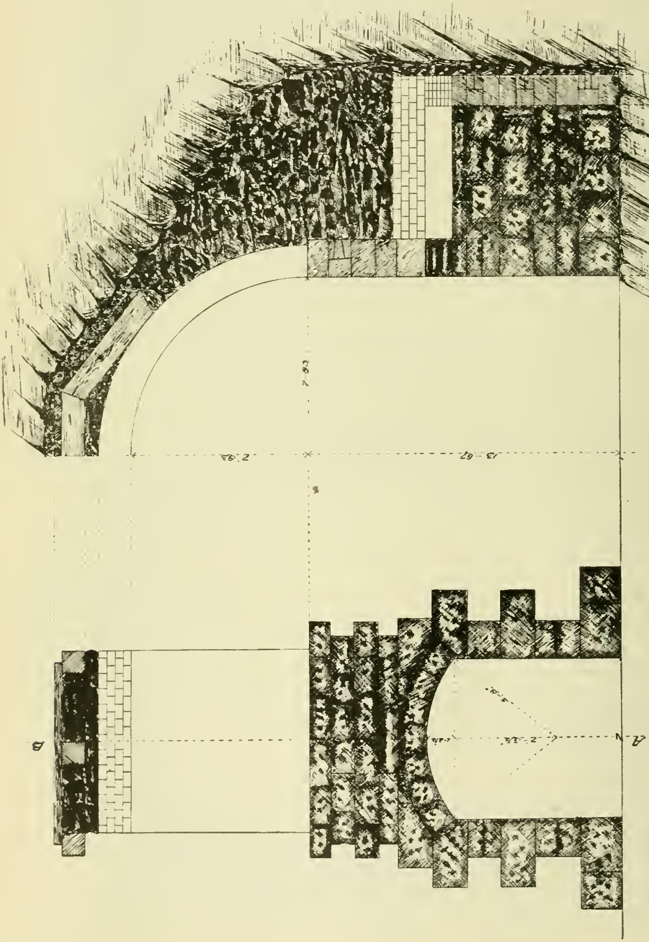
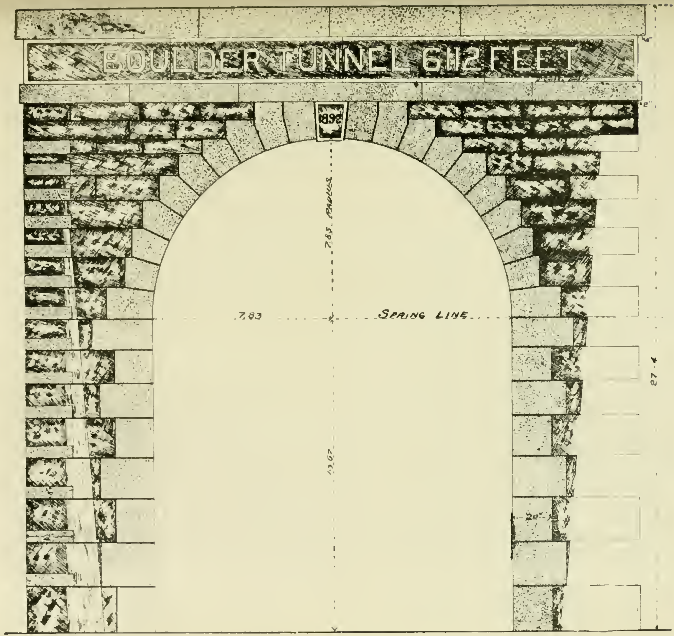
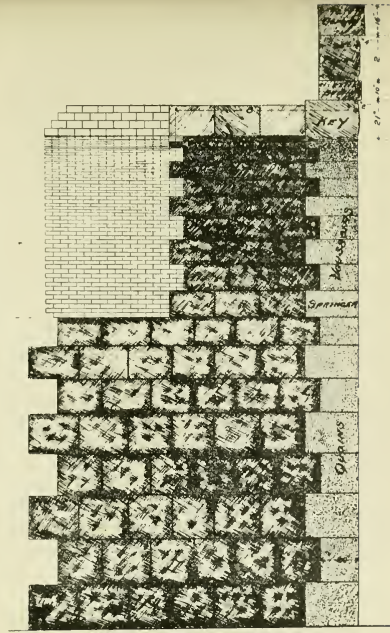


PLATE IX.—Hand-Car Recesses.



ELEVATION



LONGITUDINAL SECTION

PLATE X.—Details of Portals,

rings a good coat of cement must be spread on such outer surface.

The above quotations are from the specifications written by Mr. E. H. Beckler, Chief Engineer, under whose direction the work has been carried on.

LABOR. Since the commencement of the work only a single crew of brick and stone masons has been employed. In order to prepare the sections for these masons it is necessary to have timber and trimming crews at work throughout the whole day of twenty-four hours, so that a work engine has been in constant attendance and two train crews to operate same, besides operators and engineering service. The single masons crews are able to complete 8 feet of side walls and arch in 24 hours. The cost per foot has been somewhat greater than would be the case if double crews were put on, as the present train service is sufficient to handle the extra force. The number of men actually employed at the tunnel is about 35. This includes electric light mainteance and all other labor pertaining to the work.

LIGHT. The tunnel is lighted by an Edison dynamo of 20 arc light capacity, one light being placed at each side of tunnel at all working places. Each lamp carries a coil of wire 20 or 30 feet long, which will allow its being shifted from place to place without delay. This system of lighting has been very satisfactory.

The work is being done by contract. The contractor furnishes all material and the company furnishes train service and free transportation for material.

During the year devoted to the work 1600 feet of tunnel has been completed and about one and one-half years will be required to complete the work.

METHODS AND RESULTS OF PRECISE LEVELING.

BY O. W. FERGUSON, MEMBER ENGINEERS' CLUB OF ST. LOUIS.

[Read February 15, 1893.]

Description of Instruments.

The original precise leveling instrument is made by Kern, of Aaran, Switzerland, but equally as good an instrument is made by Fauth & Co., of Washington, D. C.

The instrument has a telescope about 16 inches long, object lense 1¼ inches aperture. The eye piece is of high power.

The image of the rod is magnified by this telescope about 52 diameters, or what is the same thing, it is viewed at 1-52 of its actual

distance from the instrument. The telescope is of good defining and light-gathering power. It carries three horizontal and one vertical wire. It is held in the Y's by light spring clips—easily put in, or taken out. The striding level is used: this is necessary in a level of precision in order to make complete adjustments and to measure the errors of the instrument. The same spring clips guard this level from falling off the telescope. The boxing carries a level tube six inches long and ⅝ of an in. in diameter, graduated in divisions of 2^{mm} length; the value of one of these divisions, in angle, being from 1.8 to 3.3 seconds. Over this level stands a plain mirror at an angle of about 45 degrees, which reflects the image of the bubble to the eye of the observer. Part of the weight of the instrument is taken off the spindle by the little spring plate at its upper end.

Under the eye piece, convenient for the observer, the instrument is provided with a large milled head micrometer or elevating screw, for controlling the bubble during observation. The whole rests on a broad triangular base supported by three large leveling screws. The lower and spherical ends of these rest in corresponding sockets of the tripod head, fastened here by clips and clamp screws.

The tripod is provided with large thumb screws, these make the tripod very firm when turned up. The tripod legs are covered with canvass. The tripod shoes—an important item—are of a good pattern, being straight with the surface of the tripod leg on its under side.

The rods are made of Norway Pine; three meters long, of a T cross-section, firmly put together to prevent warping; they terminate on an iron shoe ending in a conical steel shaft ¾ of an inch in diameter, the bottom surface is plane and at right angles to the axis of the rod. The rods are about 3½ inches on the face, painted white, very precisely graduated to the metric system to decimeters, figured between. The center of the rod is graduated in two alternating rows of black and white centimeter spaces, figured along the side. The telescope is inverting and these figures all appear normal when seen through it. The rods are supplied with a large watch level by which to keep them plumb. This level being adjusted to a plumb line *swung from* and *to* the adjusting points on the rod. There are also two handles for holding the rod. When in use, the rod rests on a foot plate, a flat plate of wrought iron an inch thick and of 18 square inches or more in area, having short spurs underneath and provided with an iron handle. In its center a cavity is turned out of the proper shape to receive the end of the rod, but somewhat larger. The bottom of this cavity is spherical and on its highest point the rod rests. The Kern instruments came from the shop with the ends of the rods spherical and the floor of the foot plate flat, but this was wrong in principle, as any lateral movement of the rod changed its height. so we changed the order. We

have made an iron pin to take the place of the foot plate. It is about ten inches long, to be driven by a mallet—it terminates in an enlarged head having a cavity similar to the foot plate, for receiving the rod. It is more suitable, except on hard, sandy or gravely ground, than the foot plate. The large four-ribbed canvass covered umbrella, with a spread of five feet, affords sufficient protection from a wind, up to a velocity of from twelve to fifteen miles an hour. It is brought close, its long handle passing under the center of the instrument. The large sun-umbrella, held high up and as far away from the instrument as it can be to let in the light, protects the instrument greatly from the heat of the sun.

Organization of Party.

The party is composed of observer, recorder, two rodmen, an umbrella man and an axeman who also assists with the umbrellas.

Sources of Error.

The failure to obtain good results in leveling will arise from one or more of the following conditions, and it is the business of the precise leveler to reduce all these to a small factor.

1. The line of collimation not concentric to the rings of the telescope. (Error of collimation.)

2. The tangent to the center position of the bubble, in the tube, not parallel to the supporting surfaces of the telescope rings. (Error of inclination.)

3. Unequal radii of the two telescope rings. (Inequality of rings.)

4. The image of the graduation of the rod not in the plane of the wires, or the eyepiece not focused on the wires. (Error of parallax.)

5. Failure of the bubble to indicate its true position, from imperfections in the curvature of the tube, viscosity of the liquid or from the instrument being under strain and slowly moving.

6. The horizontal wires of the telescope not horizontal.

7. Error in reading the true position of the wire on the rod.

8. The rod not held vertical.

9. Rising or sinking of the ground on which the tripod is set.

10. Rising or sinking of the ground on which the rod is set.

11. The rising or settling of the tripod away from the ground.

12. The rising or settling of the rod support away from the ground.

13. Errors from wind or sun often of the nature of a *constant*.

14. Bench marks changing their elevation during work.

15. Difference in refraction of the medium of back sight from foresight.

16. Imperfect graduation of the rods used.

17. Blunders, as. the rodman holding on the wrong point: the observer calling off the wrong number; the recorder not writing down what was called. or lastly errors in computation.

It is evident that the observer is not the only factor necessary to secure good results. On every member of the party in a significant degree depends the success of this work.

Adjustments Necessary.

On starting work the instrument is first examined, and adjustments made where necessary, so that these errors are within the errors of observation. The adjustments necessary to be looked after daily and occasionally are:

1st. To make the tangent to the level tube at its center at right angles to the vertical axis of the instrument. This is done by turning the elevating screw and leveling up alternately until the bubble will remain approximately in the center while the telescope is turned in azimuth 180 degrees.

2d. Lateral adjustment of the level tube, to bring its axis in the same vertical plane as the axis of the telescope, done by sliding the level from side to side through a small angle and adjusting the lateral screws until the bubble remains in the same place.

3d. To adjust the three horizontal wires so that their mean position will be horizontal. To do this, find the mean reading of the three wires on a rod in the quarter of the field well to the right of the vertical wire, another well to the left. Observe the difference and turn up the stop screw until these means are the same. Observe then the direction of the vertical wire, if not vertical it must remain so.

4th. To make the tangent to the level tube at its center, parallel to the line of the surfaces of the telescope rings on which the striding level stands, that is to make the legs of the striding level of equal length, done by reversing the level on the telescope and adjusting until the bubble reads the same in both positions.

5th. To adjust the collimation, that is to make the intersection of the vertical wire with the mean of the three horizontal wires coincide with the optical axis of the telescope. This is done by reading the three wires with the telescope in the normal and then in the inverted position and adjusting the reticule until these means are the same.

6th. To adjust the large watch level of the rods so that when the bubble occupies the center position the rod will be vertical. The rod is held so that the point of plumbob comes to the adjusting point, which brings the axis of the rod parallel to the string; the bubble is then made to stand in the center.

Instrumental Functions.

Before beginning work there are certain values of the instrument to be determined that are quite constant functions, subject to only small changes for considerable periods of time. These are, first the value in angle (n) of one division of the level tube, and, for convenience, the distance (s) at which this subtends one millimeter.

The value of one division is found by reading the rod at a measured distance, say 50^{m} from the instrument, with the bubble first on one side and then on the other side of the center. The readings of the ends of the bubble are always taken, the difference of end readings giving twice the movement of the bubble. Then the movement of the mean wire on the rod, between the two positions of the bubble, is equal to the base, in the same units, $\times$ number of divisions through which the bubble has moved $\times\ n \times$ sin. of $1''$. From this we get one determination of n. We usually find this value by the mean of ten determinations to within about $\pm\ 0''.157$. Finding then the natural sine of n for 1^{m} and dividing unity by this we have the distance at which one division subtends 1^{mm}.

2. The second constant to be determined is the angle formed by the line joining the centers of the telescope rings with a line in the same plane tangent to the outer surfaces of these rings.

To find this angle we set the instrument, not on the tripod, but directly on a firm rock or on the heads of spikes in a stump. Then by a system of end readings of the bubble, with tube set in both positions on the telescope, which is also alternately changed end for end, we find this quantity, thus:

EYE END OF TEL. NORTH.				EYE END OF TEL. SOUTH.				
BUBBLE READINGS.				BUBBLE READINGS.				
Eye end Level N.		Eye End Level S.		Eye end Level N.		Eye end Level S.		
N. End	S. End	N. End	S. End	N. End	S. End	N End	S. End	
14.0	7.3	15.6	5.8	0.7	20.8	5.7	15.8	$\frac{-30.2-16.5}{2\times2\times2\times2}=-2.919$ Divisions
+6.7		+9.8		—20.1		—10.1		
+16.5=4 times the inclination of tel. in this position.				—30.2=4 times the inclination of the tel. in this position.				

This gives one determination of the value (p) sought, in divisions of the tube, which having been found gives p in seconds of angle.

The mean of ten determinations in this way usually gives this value to within $\pm$ 0.1 second. In the example given the eye ring is large and the sign of the correction is minus.

3. The third constant to be determined is the value of each wire interval of the telescope and the total interval. This is done by measuring a base 100^{m} with a tack in a stake at every 10^{m}. The

rod is then successively held on these points and three readings and their means taken at each station. This gives the relative and total value of the intervals and enables us to find the distance corresponding to any given interval. All of the precise level telescopes from the makers make the total interval subtend about 10^{mm} for every meter distant. Of late years we have had these wires put only half so far apart, so that the total interval subtends only 5^{mm} per m., which is better, it brings the wires in a better part of the field, the apparent angle between them being only half as much they are quicker seen, the lower wire line of sight is farther away from the ground and the upper wire line of sight is less likely to be interfered with by higher objects.

4. The next constant sought is what is called the "*A*" of the rods.

The graduations of the precise level rods do not begin at the bottom but at a place about 50^{mm} above this. This distance determines the quantity called "*A*" of rod. This distance should be made of the same length on each of two rods to be used with the same instrument. This equality is obtained to a high degree of accuracy, by filing off the longer rod until, when held on a spike 8 or 10^{m} distance and the center-wire of the telescope set on the first graduation of the rod, the bubble will come to the same position for both rods.

In the same way, after the "*A*"s have been made equal, by setting the center wire on the last graduation of the rods, alternately, and reading the bubble, their comparative lengths can be found.

5th constant. The absolute lengths of the rods used should be determined by comparison with a standard both at the beginning and at the end of each season's work.

Form of Keeping Notes.

A page of the field book is given with the observation of one setting, one back sight and one fore sight recorded. The back sight occupies the left hand page and the foresight the right hand page of the book.

Field Operations.

We are now ready to describe the field operations. The rear rodman is on the bench, the observer has selected the length of his sight, and place to set up according to locality and conditions of weather, and has tested the adjustments of the instrument. The wind umbrella is keeping off the wind and the sun umbrella the sun. The other rodman has paced from bench to instrument and gone what he finds to be the same distance ahead and set his point. The observer, with fingers hold of the elevating screw and eye at the eye piece observing the bubble, brings the latter to the center, and by testing with this elevating screw finds whether it is in stable or unstable equilibrium

FORM OF FIELD BOOK.

ABOUT $^7/_{10}$ FULL SIZE.

LEFT PAGE. | **RIGHT PAGE.**

43 *Locality*.................. | *Observer*.......................... *Level No*....

Date....................

Direction.................... | *Recorder*.......................... *Tube No*....

BACK SIGHT. | FORE SIGHT.

WIRE READINGS.	MEANS.	WIRE INTERVALS.	BUBBLE. EYE	BUBBLE. OBJ	ROD	REMARKS.	WIRE READINGS.	MEANS.	WIRE INTERVALS.	BUBBLE EYE	BUBBLE OBJ	ROD	REMARKS.
1009		175	11.5	11.5	10	T. B M. 30	1686		187	11.5	11.5	13	P. B M. 20
1184	1185.0	178					1873	1874.2	190.5				
1362		353					2063.5		377.5				

and whether its apparent position indicates its true position or not. Sometimes this is done quickly, at others it will require two minutes; then he glances at the lower wire and estimates its position on the centimeter space and calls out the last two figures of the reading, the centimeters and millimeters; then watching the bubble more than the rod reads in like manner the second and third wires; then he goes back to the first wire and reads off the whole reading, also of second and last wire. If in his estimation he has a fraction of a millimeter remaining it is called off with the last wire.

The recorder also writes down the length of bubble, which the observer calls off first, the number of rod read on, and what it was held on, and takes out the intervals by subtracting first wire from second and second from third. Knowing the relative values of these intervals he notices if their difference is about right. If not, investigation of the reading is made at the time on the ground. He sums these intervals for total interval, and writes in the mean of the three wire readings for the back sight. This mean is gotten quickly by adding to or subtracting from the middle wire one-third of the difference of the two intervals according, as the first interval is smaller or larger than the second. The foresight is then taken in the same manner, and when completed the back rodman is called up. As soon as recorded, the recorder notices if the total intervals of this backsight and foresight are equal. He draws a line with his pen at the top of the book about ½ of an inch long. If the backsight interval was 8^{mm} greater than the foresight interval, on the left hand side of the line at the top he writes a small 8, if the foresight proved to be longer, he writes the amount on the right hand side of the line. The recorder observes that 8^{mm} of interval represents about two steps—so as the rodman, going forward, reaches the instrument, at its second setting, the recorder says to him, "go two long." After these shots are recorded, recorder finds he went long so that the foresight was 11^{mm} longer than the backsight. Then just below the 8 and on the right side of the line he writes a figure 3. This last number then will express the difference in the sums of all backsights and all foresights no matter how far the line has been carried. The difference between the continuous sums of back and foresights is thus kept track of and made small.

When the run is about completed for the last setting the observer sets up temporarily at about the middle point between rods and reads the total interval on each rod: at the same time he is told by the recorder how the summations stand and then sets his instrument at such a point that the total intervals of all back sights will equal the total intervals of all foresights, and he generally misses it less than a meter.

The same party then runs the same stretch in the reverse direction, to the starting point. The recorder in the meantime has the mean

readings and total intervals summed for each page. He calls these off to the observer who takes out the differences for both runs, and determines, in about three minutes, if the error of closure is sufficiently small; if not, other pairs of lines are run over the same stretch until the required degree of refinement is reached.

Checking Notes.

The rodmen, in the office, then check over the recorder's quantities, signing each page. The recorder then closes the runs, which consists in giving the difference of elevation from point to point, and their distance apart. In the direct or forward line, in the summations, the backsights are called "+" and the foresights "—." In the reverse run the backsights are called "—" in their sum, and the foresights are called "+." Then the difference, with its sign, will indicate whether the forward bench is above or below the rear bench, from which it was run, by the sign being + or —, in all cases. Then in writing out the difference of elevation, the forward bench is invariably stated as being above or below the bench back in the system from which it was determined. The observer then checks these closures.

Disturbance from Expansion.

The sun shining on the tripod or instrument, expands this side more than the opposite side, and causes the bubble to keep moving slowly towards the sun, obliging the observer to continuously turn the elevating screw, in order to hold the bubble in place. The umbrellas prevent a large part of this disturbance. It is reduced still more by every time setting the tripod legs up in the same relative position to the sun. The effect of the sun shining on the level tube or boxing is mischievous. It should at all times be kept in the shade and at an even temperature. A good deal of the time the striding level must be carried in the hand, and so is subject to another source of unequal heating. The ill effects of this is prevented by making this heating symmetrical about the center of the tube, by taking hold of it in the middle, so that the metallic ends are the same distance from the hands, and secondly, by reducing this heating to a practical minimum by carrying it by the fingers; making the surface of contact very small and allowing free circulation of air around it. The bubble tube being encased in a wooden box, it is practically uninfluenced by the heat of the hand in carrying.

Care of the Instrument.

The application of a good deal of mechanical skill and judgment is required to properly clean the parts and bearings of the precise level.

The best watch oil should be used to clean with, but very little should be left on. In the places where dust accumulates and grinds the oil should be all wiped off, and the part cleaned frequently.

The application of experience and mechanical judgment is needed

to give the proper bearing to the parts, the proper weight on the spindle, the right tension on all of the split nuts, making the bearings sufficiently snug, yet not so tight that as bad an effect will be produced by the application of the force needed to turn them.

Errors of Instrument to be Measured.

At the end of the day's work the errors of the instrument are measured, to be applied to the amount of the excess of the sums of back sights or fore sights.

1st. We measure the error of collimation by taking the mean of the wire readings on a rod at about 50^{m} distant with telescope in the normal position, and then in the inverted position. Thus if the mean normal reading is 1961.4^{mm} and the mean inverted reading is 1961.7^{mm} and the distance of the rod from the instrument is 46^{m}, then the correction for collimation in millimeters per meter to be applied to the sum of the mean wire readings on the side where the excess exists, with its sign, is given by

$$\frac{1961.7 - 1961.4}{2 \times 46} = + 0.003^{mm} \text{ per m.}$$

2nd. We measure the error of inclination, which is the error in the striding level, by taking the end readings of the bubble, first with striding level set on the telescope in the direct or usual position, then in the reverse position, several times, alternately. The end reading of the bubble towards the eye piece is called "+" and the one towards the objective "—." Thus

Measuring the correction for inclination:

	Level Direct. +	Level Direct. —	Level Reverse. +	Level Reverse. —
	14.0	13.9	10.3	17.6
	14.4	13.4	10.7	17.1
	14.2	13.8		
Means	14.2	13.7	10.5	17.35
Sum	+ 0.5		— 6.85	

Then correction for collimation

$$= \frac{\overset{\text{Div.}}{-\,6.85} - \overset{\text{Div.}}{0.50}}{4 \times 80.97^{m}} = -\,0.023^{mm} \text{ per m.}$$

with proper sign to be applied to the sum of the mean wire readings on the side having the excess of lengths of sights. We divide by 4, because the end readings of the bubble give twice the actual movement of the bubble from center position, and because by reversing, the real error is only half of the apparent error. We divide by 80.97 because this is the distance (S) at which one division of the tube subtends 1^{mm} on the rod.

3rd. The correction due to want of equality of telescope rings, previously found as a constant function, and given with sign in millimeters per meter. The algebraic sum of these corrections is then multiplied by the number of meters excess and the product added to the sum of mean wires. This sum of corrections usually is about 0.030^{mm} per ^{m}, but varies largely.

The Observer makes all the Observations.

In this system, no target is used. To get a target in place the cbserver must communicate what he wishes through two human machines, and by the time he gets it where he wants it, he wants it somewhere else. Until we get a target that can be set by the thought of the observer, it will be too slow, too inaccurate and too subject to slip for precise work. If a target is used the reading is governed by its position and it is so troublesome to move it a small amount and not too much, that the observer often injures his observation by having it moved, and at other times rather persuades himself that it does not need to be disturbed when it should be.

Secondly, the observer brings the bubble to the true position and reads it himself.

Thirdly, the observhr should set up his own tripod and instrument, he will then benefit by experience on the action of different kinds of ground and set his instrument accordingly, and will attend more infallibly to the alternate clamping, loosing and adjusting of a half dozen appliances before the instrument is right to be observed with, and again before it should be removed to the next station. Thus, as should be done in all accurate work, the observer controls and makes the complete observation.

Tables made to aid computation.

To facilitate the computation of the results several tables are made out. 1st. from the observations for intervals, a table is made giving the length of any observation, from the size of the total interval. A quicker and equally accurate method, which is now used is to find the length of a stretch from the total interval and average length of shots. The spread of the wires is directly as the distance from the point in front of the objective equal to the focal length. From the observations taken, the distance of this point from the center of the instrument, also the spread of the wires for the first meter is computed. In the table then the interval of 1000, 2000 to 9000 gives the total distance for average length of shots from 30^{m} by steps of 5^{m} to 90^{m}.

2nd. From the formula for the limit of error a table is made out giving the limit of error of closure for a stretch of any length.

3rd. From the value of one division of the level tube, a table, giving the correction to the mean wire reading, for any difference of end readings of the bubble, and length of observation; but as the reading is

most always taken with end readings the same, there is very little use for this table.

4. A table giving the correction for inclination for a difference of differences of end readings of tube for 0.1, 0.2 – 0.9 division and therefore for any quantity.

4th. The error of collimation, depending on the difference of readings in millimeters and the distance of the rod from the instrument, a table having these two arguments gives the required correction in millimeter per meter.

Hindrances to Work and to good Results.

The great disturbances to precise level work are *frost*, the *wind*, the *sun*, and *irregular refraction* any one of which may be sufficient to suspend work. Other causes that interfere with the work are mud, water, spongy or soft ground.

Frost causes the bubble to be very unsteady, the tripod tends to heave out of the ground, or if the shoes are warm enough to thaw the frost, it will settle. By cutting through the frost we overcome this disturbance.

A stiff wind is a great hindrance to work, and if it gets above 20 miles an hour work must be suspended. It continually disturbs the bubble notwithstanding the umbrella, but having the protection afforded by this umbrella, the limit of endurance is first reached at the rod, it being very difficult to hold, the rod support too being thus more or less disturbed.

The influence of the sun on the ground and air is to cause many disturbing surfaces, and streaks of vapor to arise causing the air to tremble; and the greater the distance of the object, the larger the amplitude and greater the distortion. This can be overcome, in a measure, by shortening observations.

When conditions are good, observations of 100^{m} can be well taken, when the air becomes tremulous, it often becomes necessary to reduce the observation to 30^{m} which is the limit of practicability, and below which work should not be continued. But the most troublesome source of error to manage is irregular refraction. It is always stealing in with its surprises, when otherwise the conditions for work are favorable. It is then only detected by watchfulness. It occurs during the changes in the air from dry to wet, hot to cool and the reverse. In open country, it appears in the morning as the sun warms the ground; also near sunset at evening. This changing refraction will cause a wire reading to slowly change in a shot of 60^{m} length, as much as 3^{mm}. It is caused by changes in the medium through which the line of sight passes. The back sight may pass near the ground, where the air is dryer, hotter, wetter or cooler than the air through which the fore sight traverses, it lying well above the ground. Or the air may lie

in masses, so that one sight traverses a different air from the other. Again, the air slowly moved by different gentle currents, brings from a cool nook a mass of air across the line of the back sight, but before the fore sight is taken this cool, moist mass of air has given place to a warm and dry mass, that has moved in from a stubble field. The observer must look out for these phenomena, and guard against them.

One is quite sure to have one or two settinsg disturbed in this way, when passing from the cool shade of a bluff to open country where the sun is shining; also when passing creeks and ravines. There is most of this disturbance met with along the foot of bluffs, and least in open country. The observer will necessarily be watching for these disturbances, and will diminish the resulting errors by having the rodman set the rods so that the line of sight will pass well away from objects and well above the ground. In selecting places for the instrument too, make the similarity between back and fore sight as great as possible. If we have a choice of having the line of sight pass near the ground, at a point near the instrument or near the rod, choose the latter, as the amplitude of refraction will be proportionately less. If the back sight is all in the shade and the fore sight all in sunshine, we may expect some error from this. The more important precaution to take against these errors of refraction, is to reduce the length of shots materially; the separate disturbances will then be less and the compensation better.

The number of small accidental errors is increased by the number of settings; but we have found that the increased precision obtained with short shots, from better seeing, and smaller amplitude of the usual disturbances, will overcome the uncompensated accidental errors due to the greater number of observations down to 30^{m} shots.

A fresh breeze in the air has the effect to prevent this disturbance of irregular refraction, for it keeps the air uniform.

Best Time for Work.

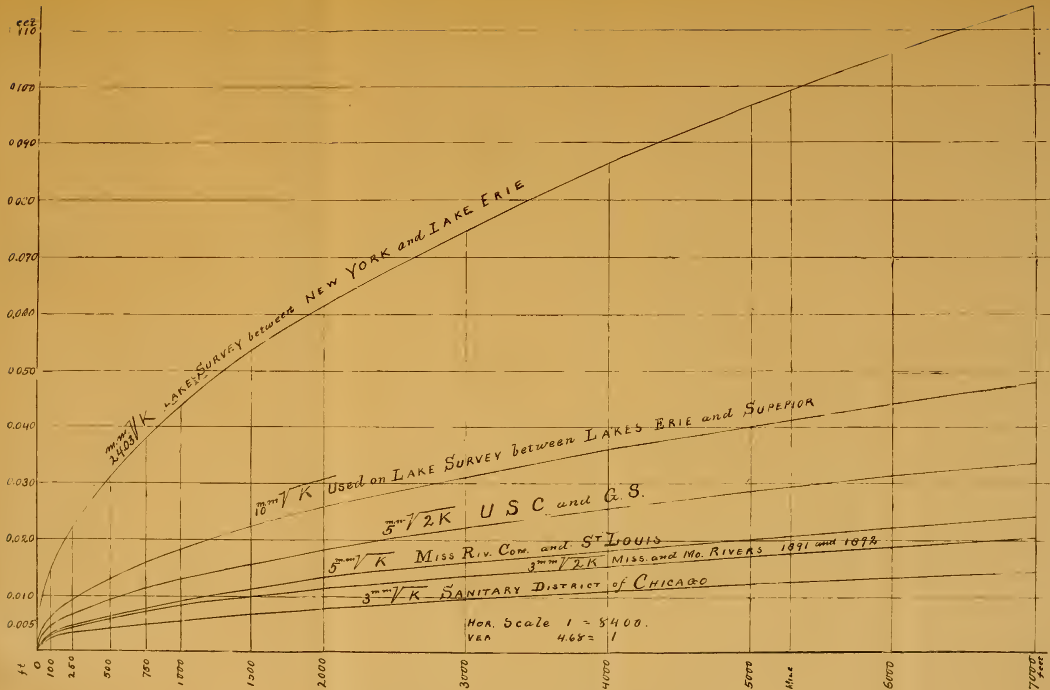
The warm months are best for precise level results; there is then no frost, the ground is mostly settled and firm, and the contrasts in temperature and moisture between the ground and air are less.

The best hours for work are during the morning up to 9 o'clock and from 3 o'clock in the afternoon, to dark, with some exceptions; cloudy days are good all day.

Limit to Error of Closure.

On all precise level work a limit of allowable error is set. The limit for the first precise level work done on the surveys of the Great Lakes was from New York to Lake Erie

$$0.1 \text{ ft.} \sqrt{\text{Distance in miles}},$$



LIMIT OF ERROR OF CLOSURE ON VARIOUS WORKS.

or to put all in the metric system, let K in every case be the distance between benches, the above then becomes — $24.03^{mm} \sqrt{K}$.

Between Lake Erie and Lake Superior it was made = $10^{mm} \sqrt{K}$.

The limit prescribed by the U. S. Coast Surv. Dept = $5^{mm} \sqrt{2K}$.

On the work done by the Mississippi River Commission, the limit has always been $5^{mm} \sqrt{K}$,

until 1891, when it was made $3^{mm} \sqrt{2K}$,

a closer limit than the previous. The limit on Mr. Colby's work for the city of St. Louis has been $5^{mm} \sqrt{K}$.

For the Sanitary District of Chicago it was $3^{mm} \sqrt{K}$.

The limit prescribed for work of the Mo. River Com., $3^{mm} \sqrt{2K}$.

These prescribe that the error of closure, or the numerical sum of the residuals of the two lines from their mean, shall not exceed this amount. The limit can only apply to stretches, not to an aggregation of stretches. These limits consider that the error of closure should increase with the square root of the distance run, or some factor of it. From 80 to 94 per cent. of the stretches come within, and usually far within, the limit.

Accidental Errors and Constants.

These errors of closure are made up of the uncompensated accidental errors of the observations, made while running the distance "K" in each direction, and the algebraic sum of all errors of a constant character, such as a heaving or settling of the ground, or of the tripod shoes or rod supports away from the ground; Thirdly, the disturbing influence of heat, and some times light of the sun, also from disturbance of the wind. The last two, sun and wind, act as a constant when their disturbing influence occur on one line, but have subsided when the reverse line is run. It shows in the residuals, and is half eliminated in the mean. If the sun and wind have both changed direction nearly 180 degrees between direct and reverse lines, and are of the same force, the total amount of this constant appears in the residuals, but is eliminated in the means. Lastly, if the sun and wind remain in approximately the same quarter during both runs the constant error enters both lines alike, but does not appear in the residuals and is not eliminated from the result.

To Detect Constant Errors.

The portion of the accidental errors that enter the residuals increases with the square root of the distance, theoretically; and if there is no constant, the sign of the residuals will be + approximately as often as they are ∓. Constant errors, of significant magnitude, will show their appearance by causing these residuals to nearly all be of the

same sign and probably of considerable magnitude. The cause must be sought out by observation and experiment, and overcome before the checking will be fine.

Uniformity of Grade of Work.

All of the parts and performances that produce an observation should be consistently refined, also all lines run over the same stretch and all stretches in the season's work should be up to about the same grade; for it is not practicable to weight the lines.

Criterion of Results.

Absolute agreement of results is not to be expected. There will be a range in the size of the residuals, and the results that come within this range are all entitled to equal weight. This range is determined by the experience of the observer, knowing what he ought to do and what he can do, from what he has done. Though the residuals, in one individual loop, would not be a measure of the accuracy of work, the range of these residuals in a large number of lines is a sure measure of the precision.

To Compute Probable Error.

From the residuals of all the lines run in one stretch, we compute the probable error (r) of the mean result, by the formula

$$0.6745 \sqrt{\frac{\Sigma v^2}{m(m-1)}}$$

where m is the number of lines.

From the probable error of each stretch, we compute the probable error of the final result (R) for each bench, from the initial point, by the consideration that at each bench the square root of the sum of the squares of the probable errors for each stretch remain uncompensated.

$$R = \sqrt{\Sigma r^2}$$

Then from the length of the whole line and the probable error (R) of the last bench, in the same way, we compute the probable error per mile or per kilometer.

Thus if c = the number of kilometers in the whole line and x = the probable error per kilometer to be found, then

$$c\,x^2 = R^2 \quad \text{and} \quad x = \frac{R}{\sqrt{c}}$$

This value x brings the, otherwise inexpressible, *degree of precision* to a tangible fact.

Work is Better than Indicated by Probable Errors.

As all lines are run in opposite directions, the constant error part of the residuals, due to rising, settling, or manipulation appears undiminished, but are eliminated in the mean result. Though our probable error is not often so large as to require an apology, yet one read-

ily sees that the probable errors computed from these residuals are too large.

Let us test this by stretches having two direct and two reverse lines, comparing the mean of the first set with the mean of the second set.

Consider, too, that we have no stretches of this kind, only those wherein the first set varied widely, and had to be re-run, and fairly may be considered to contain large accidental errors.

In the work of the season of 1892, we have 40 lines of this kind that we can use, comprising a distance of 27½ miles. The probable error of final result, considering these stretches continuous, gives $R = \pm 3.57^{mm}$. The residuals being the difference of the means from the mean of all four lines, and the probable error per kilometer $x = \pm 0.54^{mm}$

as against " " " " " of $x = \pm 0.63^{mm}$

for the whole season's work. It is interesting to notice, that the second set of lines over this 27½ miles, had the effect to change the elevations only $+ 0.84^{mm}$. There were, it should be noticed, seven other stretches of this class, not included in the above, where the second set of lines developed the existence of a line to be rejected in the first set. It is always the case, in large errors of closure, that we can not be sure whether the discrepancy comes from constants, want of compensation, large accidental errors, or from blunders, and the only way to find out is to re-run the stretch.

In the last season's work, also, there were 31 of these stretches, and six others in which one line of the first set proved to be unworthy of equal weight. The 31 comprised a length of 17½ miles.

Probable error of final result,	$\pm 2.02^{mm}$
And probable error per kilometer,	$\pm 0.38^{mm}$
Probable error per kilometer of the whole season's work,	$\pm 0.58^{mm}$

And the effect of running the second set of lines over this 17½ miles was to change the elevations $- 0.77^{mm}$.

Elimination of Errors.

In precise leveling we always eliminate errors if possible. Eliminations are better than corrections, measured and applied.

In observations we many times can eliminate what we cannot correct.

There will, almost always, be some constant change though slight, in height of instrument, between observations at the same station, also in rod supports between settings. If they heave back they will cause elevations to be carried too low continuously, if they settle, the elevations will be carried too high.

From peculiarities of manipulation and habits of members of the party other constant errors arise.

In running these lines in opposite directions, the algebraic sum of all these constant errors show in the error of closure but are eliminated in the mean. It is now common to eliminate by the order of observations all of these errors made by the instrument or at the instrument, by taking alternately the back sight and at the next setting the foresight first: but whatever constant changes occur in the rod supports are contained in the errors of closure.

The errors of *telescope rings*, *collimation and inclination* that we measure as constants and apply to the excess of sights are not, after all, constants.

The striding level has a considerable movement when it sets on the telescope. We try to place it exactly the same at each setting, and to keep all dust, dirt and moisture off of these surfaces, but as this cannot be perfectly done, "*p*" is not a perfect constant. Also the errors of collimation and of inclination, from jar or expansion are subject to changes while the work is going on. Therefore though these errors are made small on the start and measured and applied at the end, there is no way so sure of preventing errors from these sources as by eliminating them, by having each fore-sight equal to its corresponding back sight.

After reading one shot the observer reads the other immediately afterwards, to reduce the changes proportional to time. To be able to do this he should see that the other sight is clear and will be ready in time. In measuring the errors of collimation or inclination, we take two direct and one inverted or three normal and two reverse readings, eliminating time error completely.

We often can eliminate errors of estimations in the wire readings, by making the same error, but of opposite sign when estimating 1^{mm} as we do on 9^{mm}, or 3 and 7, 2 and 8.

Eliminations as in Reciprocal Leveling.

An excellent illustration of the principle of eliminating errors is exemplified by the method of continuing a line of levels across a river, a quarter or half mile wide, by reciprocal leveling. I do not know when this was first devised. General C. B. Comstock, Corps of Engr's. U. S. A., introduced it on the Mississippi River. Some improvements in the way of some eliminations have been made by the precise level parties. The errors of refraction, curvature, collimation, inclination and the inequality of telescope rings are all eliminated in the observations, and too, without taking any extra observations for this special purpose. To prepare for this, we make or select a good turning-point hub on each side of the river, and a place for the instrument on each side of the river and about 10^{m} from the hubs. The figure made by the instrument stations and hubs should be a parallelogram, with instrument stations in diagonal corners and hubs in diagonal corners. The

principle is that by taking the back sight on rod on the short distance hub (1) and foresight on rod across river, on hub (2;) then crossing over to instrument station 2, taking fore-sight on short distance hub (2) and back-sight on hub, (1,) all errors of the instrument and of curvature and refraction are eliminated, in the mean result. Whatever changes take place in these values, between instrument stations, half of their algebraic sum is not eliminated in the mean. The inequality of the telescope rings, curvature and refraction can only be eliminated by occupying both stations, and because refraction is more subject to change than any other, the result by two instruments occupying both stations and taking simultaneous readings give the more perfect elimination.

We also eliminate the errors of collimation and inclination in the observations, thus

1.	Take back sight on rod on short distance hub 1	Tel. Normal,	Level	Direct.
2.	“ fore sight “ “ across river on hub 2	“	“	“
3.	“ “ “ “ “ “ “ “ “ 2	“	“	Reversed.
4.	“ “ “ “ “ “ “ “ “ 2	“ Inverted,	“	“
5.	“ “ “ “ “ “ “ “ “ 2	“	“	Direct.
6.	“ back “ “ “ on short distance hub 1	“	“	Reversed.

Then cross the river and take these same corresponding readings on hubs 2 and 1 as we have taken on hubs 1 and 2.

The difference of means of all back-sights and all fore-sights will give the difference in elevation between hubs 1 and 2 with all errors eliminated.

Tabulation.

A comprehensive tabulation of the results, as the field work progresses is of invaluable assistance. It shows at a glance the amount of work done. It gives in columns:—

1. Name and number of bench mark under consideration.

2. The bench mark from which it was determined.

3-4-5-6. Book page and date of the work, A. M. or P. M.

7. Length of the stretch.

8. Total length of main line from initial point, and total length of all line.

9. Name of observer.

10. Direction that each line was run.

11. Difference of elevation as determined by each line and their mean, with signs.

12. Residuals of each line from the mean, with signs.

13. Algebraic summation of the residuals of the direct and reverse lines from the start—thus giving the total variation of the two lines at any point.

14. The probable error of each stretch.

15. The probable error of final result to each bench successively.

16. The algebraic summation of the residuals of the direct and re-

verse lines of each observer continuously showing the sign and amount of his tendency to constant errors.

17-18-19. Elevation, former elevations and divergence.

Profile.

From the length of stretches and the residuals of all lines, we plot a profile of the errors of all lines. The axis of the profile is a straight line and is the mean of all lines. The direct line is shown as a full line, reverse line as a broken line and the work of different observers may be shown in the color of the inks used. It gives the names of places and things crossed and the relative position of all bench marks in the system.

Length of each stretch and total length, errors of closure of each stretch and divergence of each line from the mean. It shows the errors of closure between direct and reverse work between any two benches in the system.

Accuracy of an Observation.

The accuracy of an observation has been a good deal increased in late years. Formerly two determinations of the difference of elevations of two points 120 meters apart, by the instrument set 60^{m} from either, under good conditions, was expected to be from 0.2^{mm} to 1.2^{mm}, now we would expect this error of closure to be from 0.0 to 0.7^{mm} and as often under 0.3 as over it.

Estimating the Millimeters from the Centimeters.

The finest graduations on the rods are centimeter spaces. When the average levelman discovers this frightful fact, he knows enough about precise levels; he prefers to set a target a centimeter wrong and then be able to read the target to 0.001 of a foot. Target readings are what count!

On these centimeter spaces, by the position of the wires, the millimeters are estimated, the estimation is decimal, and quite natural.

These estimations are made much more correctly than usually supposed. Whether the rod is 20^{m} distant or 90^{m} distant the estimation is made decimally and with equal facility; of course, the amplitude of small disturbances at the distance 90^{m} makes the decimal position of the wire more uncertain, and consequently it takes more time to get the reading. To estimate the reading, we need to look at both parts of the 10^{mm} space into which the wire cuts it. The middle position, 5^{mm} point, is easily detected. We can tell pretty closely the proportion $^{1}{}_{10} = 1^{mm}$, or if the space appears a good deal less we will not be much wrong to call it 0.5^{mm}. One-third of the space is $3\frac{1}{3}^{mm}$ $\frac{1}{4}$ is $2\frac{1}{2}^{mm}$ and so, by different considerations, approximations, and eliminations from one wire to the other we can often obtain these readings to 0.3 of a millimeter all of which is done quite quickly.

Compensation of Errors.

We now are brought to consider the working of the law of compensation. Notwithstanding our efforts towards precision, our results would be relatively wild, were it not for the pretty continuous operation of compensation.

1. Pretty good compensation of the errors we do make in estimating the millimeters of the wire readings may be looked for as much as that the penny is to approximately fall head up as often as tail up.

2. Errors of the readings due to disturbances and accidental errors are compensating in the same stretch. If they accumulate, or act as constants they will be pretty largely eliminated in the mean.

3. Errors induced by the sun or wind not perfectly eliminated in the stretches, are compensating in the season's work.

4. Errors arising from some sudden changes in the adjustments of the instrument may compensate in the stretch—they also have a season compensation.

Average Length of Stretch.

The average length of a stretch or distance between benches on the main line during the last two years is about 1200^m or ¾ of a mile.

Reliability of Results.

To comprehend the degree of reliability of the work, consider that in reading the three wires there are three separate readings, that also must show a definite relation with each other. Reading carelessly or blindly will not check out, any oftener than you can go through the three steps successfully of 1st, tossing out a kernel of wheat and have it come a definite distance from a certain crack in the floor.

2nd. Carelessly throw out a second that shall rest a definite distance from the crack and from the first kernel.

3rd. Carelessly throw out a third that will happen to rest at a definite distance from the crack and the other two kernels of wheat.

If all three wires are read wrongly, by the same amount, it cannot be detected by the intervals.

But if we were placing the kernels of wheat and got one 100^{mm} wrong, we would not be likely to get the second also wrong 100^{mm}, it would be quite impossible to also get the third one wrong—all with different environments. But if this should strangely happen, what chance is there that it will also happen in the line run in the opposite direction? In my experience I do not know of its occurring, and never heard of a case. I know of only two observations, wherein all three wires, were, for some unknown reason, recorded each one meter wrong; one of these happened in my own experience; the circumstances were, however, peculiar.

One line of precise levels is an unfailing measure of the difference of elevation within narrow limits, but as the rodmen sometimes

make mistakes, and for elimination, the reverse line is necessary.

Let us test the certainty of one line with the light of experience.

During the season of 1891, in 768 loops or stretches, 1536 lines, done by the Mississippi River Commission under the direction of Capt. Carl F. Palfrey, Corps of Engineers, U. S. A., only one line showed a discrepancy from good means as large as 18.1^{mm}. Only eight lines showed a discrepancy from good means as large as 10^{mm}, being mostly the work of inexperienced observers.

In 1892, in a total of 2,180 lines run by the Missouri River Commission, under the direction of 1st. Lieut. J. C. Sanford, Corps of Engineers, U. S. A.,

Only one line showed an error as large as 10^{mm} (just 10^{mm}).
" six " " " " between 5^{mm} and 10^{mm}.
And ten " " " " " 3^{mm} and 5^{mm}.

We have seen how small errors of reading are detected by destroying the ratio between wire intervals, how constants are eliminated in the means, how the working of the law of compensation cuts down accidental errors, and the above considerations, which can also be shown from the work of other seasons, demonstrate how improbable it is for large errors to creep into the work.

Degree of Precision.

The chances of the first two lines checking inside of the limit, has been growing greater during recent years, though the limit allowed is some finer. Also the probable error per kilometer has been decreasing. The method of alternating, in time of reading back and fore sights should show some improvement.

During former years, from fifteen to twenty per cent. of our stretches had to be re-run, and the probable error per kilometer was from ± 1.25^{mm} to ± 0.67^{mm}. In the season of 1891, of the 484.7 kilometers in the main line, 13 per cent. was run more than twice, and the probable error per kilometer was ± 0.63^{mm}.

During the season of 1892, of the 624 kilometers in the main line, 5.3 per cent. was run more than twice, and the probable error per kilometer was ± 0.58^{mm}.

Rate of Progress.

Up to 1879 it seems that about twenty-five miles a month was the progress of a party, running two instruments; since that time progress has been greatly increased, so that one party running two instruments completes from 50 to 65 miles a month.

Speed of Doing Work.

A good party under average favorable conditions and good effort will run a mile of line in 1 h. 20 min. Under favorable conditions the party can run a mile of line in an hour. Miles have been run, several times, in 45 minutes. It is to be understood that these observations

are always of about the same grade of precision, the extra time is made by harder thinking, and harder work between settings.

A reasonably quick observation can also be a good and complete observation. A good observer must be easy, ready, and fearless, instead of being anxious, a little behind, fearful, and uncertain. One good look, with everything right, is as good as another.

Permanency of Benches.

Since 1879, the Mississippi and Missouri Commissions have established along a very large portion of these rivers, a system of permanent triangulation points and bench marks, whose geodetic positions are mostly known. There are of one kind and another as many as two each mile. They furnish a framework for making concordant surveys at any place without any preliminary trouble, and will be of great value in the future. Prior to this, the information of special surveys was not of permanent value, for in a few years the points were all gone. Precise Levels will prove to be the cheapest work done on the rivers, for when precise levels are run, attention is paid to leaving a goodly number of permanent bench marks.

Cost of Field Work.

The cost of a mile of completed work of precise levels has been from $18 to $21 per mile, for field work.

Amount of this Work done.

A good deal of Precise Leveling work has been done in Europe. The U. S. Coast Survey department has been doing precise level work since 1875. One line, passing through St. Louis, and mostly completed is projected across the continent. Last season they ran a line across northern Florida.

General C. B. Comstock, Corps of Engr's U. S. A. introduced the system on the survey of the Great Lakes and on the river work.

The Mississippi River Commission have a line of precise levels and permanent bench marks from Biloxi (Sea Level) by way of New Orleans and Savanna, Ill., to Chicago, also a line running on up from Savanna to St. Paul and Duluth. The Missouri River Commission have precise levels from St. Louis to Sioux City. The city of St. Louis, through the influence of Robert E. McMath, has an extended system of Precise Levels. I believe that no city in the United States, if in the world, has as correct and extended a system of Precise bench marks as this city. The Chicago Sanitary District, through the urgent recommendation of Mr. L. E. Cooley and Wm. T. Blunt, have precise levels all along the Chicago River and on down the Des Plaines Valley, to the Kankakee, below Joliet. The Lake survey corps carried precise levels, of a rather primitive quality, from Sandy Hook (Sea Level) at New York, to Albany, then along the canal to Lake Ontario, then by gauging and levels to Chicago. In this grand polygon, of 4000 miles, the error of

closure at Chicago was found to be one foot If we assume that there is no error at all in this polygon, the sea level at Biloxi, on the Gulf is 1.0 ft. higher than at Sandy Hook, New York.

The polygon of something like 1100 miles extending from Savanna to Chicago, Milwaukee, Duluth and St. Paul back to Savanna, closes within 5 inches.

Difference between Precise and Common Levels.

The common system of leveling is not to be compared to the precise system. It is a different business. The common system is very expeditious for giving the elevation of points as soon as read to.

The precise level would not take its place. Its field is finding the difference of elevation of extreme points for carrying long lines of levels.

One division of the common level has a value of about 10 sec. usually, the same length division of precise tube has a value of about 2½ sec.

With the common system there arise large and unknown differences of back and fore sights, with no way, at all direct or convenient, for measuring errors. There is but one wire; if this is read wrongly there is nothing to indicate it.

The peg method is the only way to adjust the common level correctly. The inequality of rings, which error is as large as 6 sec. in some precise levels, can not be detected in the common level in any other method.

False Standards of Results.

Engineers usually do not know the requirements for good leveling. They look upon the agreement of results as the end in excellency.

If it is only agreement of results, and not difference of elevation that we are looking for, they can be obtained by putting a little of this and a little of that together. If the average levelman runs a line over twice in the same direction with pretty good agreement, (and he usually does run it in the same direction even at the expense of a mile or two walking) and then runs it over in the opposite direction and varies 0.15 ft. from the other lines, he will throw this result out. He might set his level on a raft, floating down a river, and regularly take back sights and fore sights on the rodmen on shore; then he might go over the same ground again in the same direction on another raft. His results would be wonderfully concordant compared to their correctness. But if after taking the first line, he takes the second on the raft towed up stream, the accuracy of this mean determination, will be high compared to the agreement between results. This is not an unreasonable case for the more thoroughly the levelman considers that he is working on changing things, the more thoroughly he will devise to eliminate errors. I know of many miles of leveling, that have been done by

good observers, the criterion being agreement of results regardless of elimination. Some common level results published, are, on the face of them, miraculously correct; excelling any results by precise levels.

They are obtained by each levelman feeling his way along over the same points and rejecting everything but nearly identical results. I have followed some of these lines with the precise levels and found their variation from the precise level mean to be twenty times as much as their own variation.

The most perfect results of leveling would be obtained in a vacuum, but unfortunately, as nature abhors a vacuum and no more than the engineer, we shall be obliged to keep up the struggle in the air.

For many reasons also, the best results could be obtained at night when there is no unequal expansion and the wind has calmed down. The observers have tried this many times but so far have made no great success at it. It seems that the sun is also the source of light and without light we found ourselves in the dark.

THE MISSION OF A LOCAL CIVIL ENGINEERS' SOCIETY.

ANNUAL ADDRESS BY RETIRING PRESIDENT, MR. WALTER P. RICE, CIVIL ENGINEER'S CLUB OF CLEVELAND.

[Read March 14, 1893.]

What should be the mission of a Local Civil Engineer's Society, what are its obligations, and along what lines of development should it expand?

I am largely prompted in what I may say, by a contemplation of the labors and fruits of our own organization. Its mission as I conceive it, is two-fold:

1st. As an educator.

2nd. In the achievement of practical results beneficial to the public and the profession.

In the line of education, a local Society has two duties to perform, one in the line of self education, and the other in the line of Public enlightment.

With regard to the former, maximum results cannot be secured except by good aggressive discussion, which most of the societies fail to obtain,—our own being a conspicuous example.

This fault seems inherent with local organizations. It takes no root in the National order.

What is the cause of this vocal paralysis which selects only the local societies for its field? Is it perhaps due to the close and life-long

friendships existing between many of the members, a family feeling as it were, and the dislike to do or say anything in the line of discussion, tending to a rupture of our high mutual regard for each other?

Is it with apprehensive thought, "That a man is never a hero to his valet," and that our friends during the heat of a discussion, may probe deeper than would please our vanity? Or finally, is it just our native coy, modesty? Whatever the reason, we fail to obtain the interchange of practical views which we have a right to expect from the high character, and varied experience of the many talented members.

Before the profession itself can receive the full benefits of a local organization in the matter of self education, there must be more of the social element infused.

The Engineer must forsake his attitude of isolation, mingle with his brother Engineers, cultivate good friendship and interchange of ideas, establish and observe a code of professional ethics, this will lead to a closer organization, and organization in its fullest sense means power, power which if rightly directed, will remedy many of the ills that the profession is heir to.

I have always held to the personal belief that the lines should be drawn somewhat closer in local societies, so that membership should be indicative of a man's standing in his profession, as is the case to a marked degree in the American Society.

They would then become guides to public estimation and continually increase their range of influence under such stimulus.

As educators of the public, the organizations have done little. This function lies not only within their legitimate province but in my estimation is the road leading to appreciation of Engineering merit.

Our worthy ex-President, Mr. Jos. Leon Gobeille, has most ably discussed the "Status of the Civil Engineer," and the general lack of appreciation of his services by the public, both in an intellectual and financial sense, and the causes leading to it.

In this connection, I desire to enunciate the following proposition:—

That the only hope of amelioration in this direction, lies principally with the Local Engineering Societies.

Emerson once said, "The sublime point of experience is the value of a sufficient man, cube this value by the meeting of two such, of two or more such, and you have organized victory.

At any time it only needs the contemporaneous appearance of a few superior and attractive men to give a new and noble turn to the public mind."

Let the societies exert their forces in the direction of public education, let them discuss live topics, local topics, in which the public are interested: let this go hand in hand with the cultivation of a fearless, truth seeking policy, and above all things, let the organizations assume

the courage of their convictions and they will become powerful factors in the advancement of professional interests, and of their standing in the eyes of the community. I can see little hope otherwise.

The conservatism of the National Society in this particular direction, forces us to look elsewhere, and as the last thing in Pandora's box was hope, so our trust must be largely placed in the hands of the local societies.

The field is waiting and they are the proper instruments to carry out a campaign of practical education. Educate the public.

It is the ignorance of the public which fails to appreciate Engineering merit because it has no understanding of the Profession and having no understanding, places its wreath of laurel upon the wrong brow, and distributes its reward's among the undeserving.

The public is good natured and well meaning. Place the information at its command, and the remedy is reached. The argus-eyed congregation will no longer see "through a glass darkly." The home citizen of wealth, from the boundaries of his narrow financial groove, will no longer beckon to false gods, he will no longer indulge in imported Architects, Contractors etc., with the implied censure of home talent which he has not the knowledge to judge of.

The Chief Engineer of great Railways will no longer be relegated to a corporation attic with the title of Road master and attendant salary. Educate, and in the light of a broader knowledge such things will disappear, the Public will judge understandingly and with discrimination. and its rewards will be commensurate with the service rendered, and Engineering will then take the high position in public estimation and public rewards, to which it is entitled by reason of its great service to mankind, but which it has never been accorded.

Engineers should be more assertive of their prerogatives and the achievement of this most desirable result must lie mainly with the local Engineering organizations of the country.

This, and every other local association possesses the inertia of great fly wheels, lying dormant in their journals. Start them in motion and the efficiency of the machines will be developed in useful work.

Tyndall in speaking of the development of the mental faculties at the expense of the physical man, compared the result to a Hercules trying to win a boat race in a rotten shell.

Our organizations present the inexacusable spectacle of a Hercules in a staunch boat, idly drifting with the current, the common attribute of drift wood, and falling behind in the race for recognition.

Are we not collectively and individually responsible for the results, which lie within our grasp and which we fail to secure?

Why not study the elements of motion? Perhaps our mechanical brethren can help us out of our statical condition.

Taking up the second part of our original proposition, that which relates to the achievement of results beneficial to the Public and the profession.

Let the societies establish or recognize a code of professional ethics, the sooner the better.

The professional journals are doing all that is possible to crystallize sentiment in this and other respects, but the members of the profession must shake off their lethargy and assist in the reforms.

When the day comes that the local society to a certain extent vouches for its members, when membership means to the general public what the degree of C. E. fails to convey, then another great step has been taken.

Let the societies influence proper legislation for the conduct of public works.

Good legislation in this quarter can hardly be expected from men who tread in other walks of life, no matter what degree of ability they may possess.

Just twelve years ago, the "JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES" heralded the first step toward a union of local societies; another step was taken in the concerted and united action of many of the societies in support of the National Public Works bill, a laudable and praiseworthy effort to give the United States Government a well digested system of internal improvements. A few more steps, and there looms up a confederation of Engineering Societies, with its grand possibilities.

Such a confederation can be no menace to the National Societies. It would have functions peculiarly its own, being both National and Local in character. It would be capable of exerting a tremendous influence in up-lifting and placing upon the high eminence to which it has incontestible claims, what has justly been denominated in the broad sense of the word, as the only productive Profession.

In conclusion, as this will be the last time I shall address a formal meeting as President, I desire to express my appreciation of the honor conferred and to thank the members for the leniency which they have extended in behalf of any dereliction of duty, which I might be answerable for.

To my brother officers during the past year, I desire to express thanks and regrets at the severance of pleasant official relations, and to say to the Club, that in prompt attention and performance of duties, these gentlemen deserve the hearty commendations of all.

ELECTRICAL SCIENCE.

Report of Progress in Electrical Science for the Past Year, By E. P. Roberts, Member Civil Engineer's Club of Cleveland.

[Read March 14, 1893.]

The most striking developments in electrical science have been along the lines made public by Hertz, Tesla and others. Quite probably some of these investigations will have important bearing on commercial matters in the near future, but as yet they are not a factor in engineering projects.

One problem in engineering, to the solving of which engineers have always looked for electrical means, is that of the transmission of power. In this line, many important plants have been erected during the past year, the most notable one being an experimental plant erected at Frankfort last summer, which transmitted power from a turbine 108 miles distant and respecting which full accounts have appeared in the technical journals. As will be remembered, the Frankfort experiment was with the triphase and step-up and step-down converters and it was found desirable to employ a very low frequency of alternations, about twenty per second being determined upon as most desirable.

In this country, the Westinghouse Company has installed an interesting plant at Telluride, Colo., operating a 100 H. P. synchronous motor distant three miles from the generator, the generator being driven by a Pelton water-wheel under a 320 foot head. The voltage used is 3,000. The combined efficiency of generator and motor is stated to be 83½ per cent. at full load and 74 per cent, at half load. The alternations are 166 per second.

The transmission of power on a large scale is rapidly approaching realization at Niagara Falls. All the technical papers have had more or less complete descriptions of the plans proposed, as far as same have yet been decided upon, and electrical transmission will in all probability do the greater portion of the work.

During the past year, electric railways have had a very large growth and Cleveland is noted amongst cities using electric roads, not only for its pioneer work, but for the present condition of its roads and for the variety of systems, electrical and mechanical, the principal electrical systems all having a foothold, some being "in it with both feet," and the dynamos being driven by high speed engines, by Corliss engines using shafting, by Corliss engines belted direct, and by vertical engines of the marine type directly connected to multipolar generators. It is stated that up to October, there were 469 electric railways, opera-

ting 8,000 motor cars and 4,000 trail cars and involving a capital stock of about $206,000,000. There now seems to be a considerable probability that the St. Louis Chicago road will be erected and the problems suggested in connection with the engineering now progressing on the plant are very fruitful. It is hoped the stock will be equally so.

At Liverpool, England, an electric overhead road has been built and the cars have been tested at a speed of over 50 miles an hour. An underground road in London is being successfully operated and others are being projected, some of them now being under course of construction in various European capitals.

Prof. Benjamin states that the most marked advance in electrical science has been in the line of electric railways and, as proof of his assertion, he cites the four cent fare.

The application of electric motors to mining machinery has made great progress recently, some of the most notable installations being those in Leavenworth, Kan., where the power of a 300 H P. engine is transmitted electrically to motors used for pumping, hauling, etc., and the plant in Streator, Ill., utilizing about 250 H. P. in a similar manner, the plant of the Crescent Coal & Coke Co., in Jacksonville, Ohio, 225 H. P. and about to install an equal amount, about half of which power is used in hauling, the other half in indicating, drilling, pumping, etc.

I am pleased to state that the man who is responsible for the most of this work is with us this evening and as I am a member of the Committee on Social Intercourse, which Committee, I believe, has no official existence, although the Chairman stated that we would continue to exercise our functions, I would request that members of the Club assist me in welcoming Mr. Sperry to our Club Rooms this evening and I sincerely trust we shall have the honor soon of greeting him as a member.

In electric lighting, as in power transmission, larger generators are being built. Many are slow speed and direct connected, thus following a practice which has been developed in Europe. In this connection, it may be of interest to note the starting in Chicago of a branch house of the famous firm of Siemens & Halske. Many improvements in station designing, particularly as to reliability and economy of operation, have been introduced in the past year. Lighting at long distances has also been developed, one of the most notable in this country being in Portland, Oregon, where high voltage, as I recollect it 3,000 volts, is generated direct at the dynamos and transmitted twelve miles to step-down transformers, which again transmit it at 1,000 volts to transformers furnishing 50 or 100 volts. The step-up and step-down transformer system is being installed in California.

The litigation of patents has been very sharp during the past year

and especially so with reference to the incandescent lamp, the exact status of which is still undecided.

The long distance telephone line, the more general use of metallic circuits and long distance phones and the placing underground of wires and the no longer claiming of the earth by the telephone companies, even although the parent company is making strenuous efforts for a new lease of life, have been possibly the most notable events in recent telephone matters.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

ASSOCIATION OF ENGINEERING SOCIETIES.

Minutes of Meeting of the Board of Managers of the Association of Engineering Societies held in Chicago, August 1, 2, and 3, 1893.

A meeting of the Board of Managers of the Association of Engineering Societies convened at Room 51 Lakeside Building, Chicago, at 9 a. m. Tuesday, August 1, 1893.

The meeting formally organized with Messrs. J. B. Johnson, W. F. Goodhue, John R. Freeman, Wm. H. Searles, (Cleveland,) Wm. A. Pike, Fredk. Brooks, J. A. L. Waddell, John Nichol and Benezette Williams, Chairman. present.

The Chairman briefly laid before the meeting the questions for consideration, and after an informal discussion it was voted to adjourn until 8 a. m. the following day, Wednesday.

WEDNESDAY AUGUST 2, 1893. The adjourned meeting came to order at 8 a. m. with Benezette Williams in the chair.

There were present Messrs. John R. Freeman, Fredk. Brooks, J. B. Johnson, J. A. Ockerson, Wm. A. Pike, J. A. L. Waddell, W. F. Goodhue. F. C. Osborn, Wm. H. Searles, Benezette Williams, L. P. Morehouse and John Nichol.

The Chairman opened the meeting, and in the course of his remarks on the work of the Board tendered his resignation as Chairman.

Prof. J. B. Johnson replied and cordially urged the Chairman to reconsider his determination.

Mr. L. P. Morehouse called attention to the incompleteness of the rules governing the Board and suggested the adoption of a rule defining terms of office of officers and that such rule should come under Article 2 of the laws of the Association.

An exchange of views followed resulting in the following motion by Mr. Morehouse.

"That a Committee of three be appointed by the Chair to formulate and submit to this meeting a set of rules under which the business of the Board shall be conducted." Seconded and carried.

The Chair appointed Messrs. Johnson, Searles and Waddell as the committee under above resolution.

A discussion followed on the questions of terms of office of officers and the business connected with the publication of the JOURNAL.

The following resolution was presented by Mr. Searles, which was seconded and carried:

That when the meeting adjourns it adjourn to meet at 2 p. m. Thursday, August 3rd.

Mr. J. A Ockerson moved: "That a Committee of three be appointed by the Chair to take up business connected with the publication of the JOURNAL."

Seconded and carried.

The Chair appointed Messrs. Ockerson, Freeman and Morehouse.

Adjourned to meet at 2 p. m. Thursday, August 3, 1893.

THURSDAY, AUGUST 3, 1893. The adjourned meeting was called to order at 2 p. m. Mr. Benezette Williams in the chair:

Present: W. H. Searles, J. A. L. Waddell, J. B. Johnson, W. A. Pike Fredk. Brooks, John R. Freeman, J. A. Ockerson, L. P. Morehouse, John Nichol and Benezette Williams.

The Chairman called for the Report of the Committee on Rules.

REPORT OF COMMITTEE ON RULES.

Your committee on Rules beg leave to submit the following report:

We recommend the adoption of the Rules herewith presented, and that they take effect at once.

If this is done the election of officers at this time will be in order or later by letter ballot, and we therefore hope that our Chairman will withdraw his resignation until his successor is chosen and installed.

Respectfully submitted,

J. B. JOHNSON
J. A. L. WADDELL } Committee.
WM. H. SEARLES

RULES GOVERNING THE ELECTION OF THE OFFICERS OF THE BOARD OF MANAGERS OF THE ASSOCIATION OF ENGINEERING SOCIETIES.

1. The term of office of the Chairman and that of the Secretary and Treasurer shall be two (2) years, and shall begin on January 1, of the even years, but they shall remain in office till their successors are chosen.

2. The election of officers shall occur at any time at a called meeting of the Board, or by letter ballot between October 1, and Dec. 1, of the odd years.

3. If the election is by letter ballot, without a meeting of the Board, the Chairman shall, through the Secretary, give notice of such election prior to October 10th, of the odd years, and shall also give notice at the same time of the appointment of two tellers in one city, members of the Board, but not officers of the same, to whom the votes shall be mailed. These tellers shall open the ballots on November 1st, and report the result to the Chairman of the Board. If no one has received a majority of the votes cast for either office, the Chairman shall order a new ballot, similar to the first, but limiting the names voted for to the two receiving the highest number of votes for that office on the first ballot. The tellers shall open the second ballot on Dec. 1, and report as before. The Chairman shall then announce the result of the ballot to all the members, and the new officers shall act from the beginning of the following calendar year.

4. Vacancies in the offices of the Board may be filled at any time, either by a meeting of the Board, or by letter ballot as described in section 3. In a case of a vacancy occurring, the remaining officer shall discharge the duties of both till the vacancy is duly filled.

After a full dissension Mr. Morehouse moved: That the Report of the Committee on Rules be adopted.

Seconded and carried.

The Chairman next called for the report of the committee on business connected with the publication of the JOURNAL.

The Committee informally reported that after an investigation into the condition and prospects of the JOURNAL, it had no special recommendations to make.

A discussion followed on the condition of the advertising business in the JOURNAL. It was conceded that only through the efforts of the several societies in the Association could any hopes of any adequate advertising patronage be entertained, while only by means of such advertising patronage could any reduction in the regular assessments be expected.

Prof. J. B. Johnson moved: That each Society, member of this Association be credited with 90 per cent. of the receipts from all advertisements sent into the JOURNAL by said Society until January 1. 1895.

Seconded and carried.

Mr. John R. Freeman moved: That future JOURNALS be issued with cut leaves.

Seconded and carried.

Prof. Johnson moved: That the resignation of Chairman Benezette Williams be accepted to take effect January 1, 1894.

Seconded and carried.

Mr. W. H. Searles moved: "That the constitution be reprinted in portable form with all subsequent additions together with report of these proceedings.

Seconded and carried.

Mr. Fredk. Brooks moved:

Resolved, That the Secretary be requested to see that cuts published with linear scales bear metric linear scales, unless objection is made by the authors.

Seconded and carried.

Prof. J. B. Johnson, offered the following resolution:

Resolved, That in accepting the resignation of Mr. Benezette Williams, as Chairman of the Board of Managers of the Association of Engineering Societies, we express our regret that he feels called upon to sever his relation as Chairman, and we hereby tender him our acknowledgments of the obligation the entire Association is under to him for his continuous and unremitting efforts in behalf of the Association, he having served as Chairman of the Board from the time of its organization, in 1881. Carried.

Mr. Benezette Williams expressed his acknowledgments and thanks.

Mr. W. H. Searles moved: That the memoranda of expenses of the members attending this meeting be handed to the Secretary, and that he be authorized to assess the Societies pro rata for settlement, in accordance with previous usage.

Seconded and carried.

Before adjourning the minutes of the meeting were read and approved.

Adjourned. JOHN W. WESTON, Secretary.

BOSTON SOCIETY OF CIVIL ENGINEERS.

JUNE 21ST., 1893:—A regular meeting of the Society was held at its rooms, 36 Bromfield Street, Boston. at 8 p. m. Vice-President Albert F. Noyes in the chair. Thirty-eight members and fifteen visitors present.

The record of the last meeting was read and approved.

Messrs. Charles A. Mason and Joseph H. Wallace were elected members of the Society.

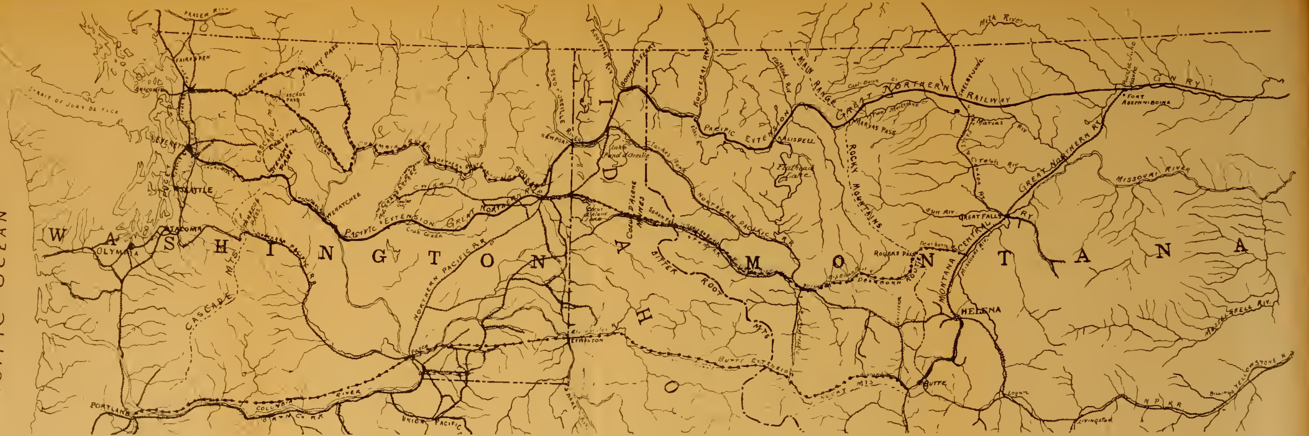
The death was announced of Thomas W. Davis, a member of the Society, which occurred April 22nd, 1893, and on motion it was voted to appoint a committee to prepare a memoir. The Chair appointed as the committee, Messrs. Charles Harris, F. O. Whitney and S. C. Ellis.

On motion of Mr. Bryant the sum of \$50 was appropriated for binding and other library expenses.

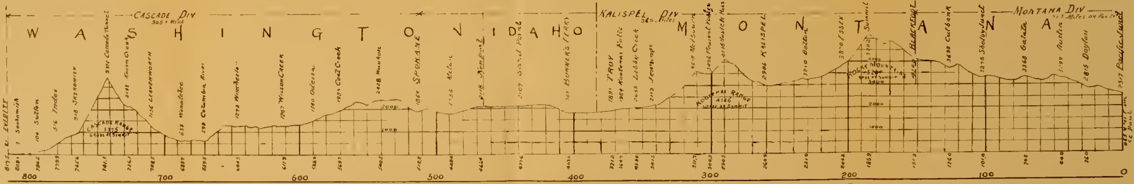
On motion of Mr. Main, a vote of thanks was extended to Mayor Mack, of Lawrence, and the Lawrence Water Board, for courtesies shown members of the Society on the occasion of the visit to that city.

The discussion on the measurement and value of water power continued from the last meeting, was then taken up. The Secretary read in the absence of the author, a discussion by Prof. G. F. Swain, and it was continued by Messrs. Tidd, FitzGerald, Main, J. W. Ellis, Hale, F. L. Fuller and L. F. Rice. The Secretary also read discussions prepared by Messrs. Porter, Frizzell and Herschel.

Adjourned. S. E. Tinkham, Secretary.



MAP OF ROUTES EXAMINED FOR EXTENSION OF GREAT NORTHERN RAILWAY.



Condensed Profile of the Pacific Extension of the Great Northern Ry

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ASSOCIATION OF ENGINEERING SOCIETIES.
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RECONNAISSANCE AND LOCATION OF THE PACIFIC EXTENSION OF THE GREAT NORTHERN RAILWAY.

BY E. H. BECKLER, MEMBER MONTANA SOCIETY CIVIL ENGINEERS.

[Presented February 11, and March 11, 1893.]

The following paper is a synopsis of two talks on the location of the above mentioned line, explained by maps and profiles showing the various routes examined, and setting forth the numerous features which led to the adoption of the route as constructed.

Books have been written which cover only the work of a few individuals for a short period. This work of the extension of the Great Northern Railway has taken the attention of more than fifty educated men for three years, with an army of followers, and a full description of their operations would fill a good sized volume.

I do not expect to give you all that such a volume would contain in my talk. It will be better to spend the time in discussing the different routes which were proposed, as most of the gentlemen here are familiar with the general methods of railroad construction.

In the years 1853 to 1855 the United States Government gave considerable attention to the question of a railroad route to the Pacific. (Act of Congress March 31st, 1853.)

The matter was considered to be of great importance, and a full account of the northern explorations can be found in the report of the Secretary of War, Vol. 1, War Department Records, a quarto volume of 650 pages, the title being "Explorations for a Railroad Route from the Mississippi to the Pacific."

These records are interesting and worthy the attention at the present time of anyone contemplating the location of a railway from the foot of the Eastern slope of the Rocky Mountains to the Pacific Coast. This volume speaks of the railroad in the singular number which is significant, as, at that time a single line of road across the Rocky Mountains was contemplated, as fulfilling all the probable needs of the country for an indefinite period of time.

This is partly explained from the fact, that, at this time, all the country West of the 100th meridian was considered practically worthless, except a strip 100 miles or less in width, along the Pacific Coast. Under such conditions without contemplating competition, and with doubts of the success, financially, of even one line, with no expectations of revenue except from through traffic, probably little attention was given to the economic problems, which enter into the question of determining the route of a Pacific railroad of to-day. Instead of a line to be constructed with Government aid, the question now is, where shall private capital be expended in the construction of a short line, with easy grades, and curves, to enable it to successfully compete with the several lines already in operation so as to give the best returns in earnings, in handling the heavy through and local business of a most valuable section of country.

Among the problems to be considered are the following:—

1. Several routes between different termini.
2. Relative distance by various routes.
3. Probable grades by various routes and helper grades.
4. Elevations and depressions, *i. e.* Rise and Fall.
5. General and specific alignment.
6. Character of country for resources for traffic.
7. Character of country for climatic conditions.
8. Convenience in operation as regards other lines of the same system.
9. Present occupation of the territory by other lines.
10. Comparative cost of construction and renewals of structures.

Some of these matters for consideration can be determined without actual survey, from examination of existing maps of the country and a knowledge of the resources and other conditions. It is evident that some points in comparison are not capable of expression with a money value. Values should be given as far as possible.

The position of the existing line between Fort Assinniboine on Milk River and the terminus of the Montana Central at Butte, made it possible for the extension to start off at one of several points, depending upon what was to be found beyond. In a mountainous country the best lines generally follow the drainage, and the possibilities as regards the general course of the routes, and the number to be examined, can be

ascertained from existing maps. In this case it was apparent that the crossing of the Rocky Mountains could be made at the head waters of the Marais, departing from the present line near Assinniboine; or, at the heads of Sun River, leaving present line at Great Falls; or at the head of Dearborn River, departing from present line at the junction of the Dearborn and Missouri Rivers; or by extending westward from Butte. It was possible to drop out of consideration the line from Great Falls and the extension from Butte by reconnaissance, without actual survey, leaving only the Assinniboine and Dearborn lines to be compared by careful detail work in running lines.

These reconnaissances showed that a line by the North Fork of the Sun River led to the Flathead Valley, to the same field occupied by the Assinniboine line, with a much greater distance and with few off-setting advantages. The South Fork of Sun River led to the Dearborn outlet, with a loss as to grades and no gain in distance. The Butte Line crossing mountains all the way west from Helena to the foot of the Western slope of the Bitter Root Range, on the Clearwater River, has four summits with an elevation greater than 5000 feet and with nearly 300 miles of distance above the elevation of 4500 feet. It was too near the region of perpetual snow to be desirable. As seen by the profile (Profile exhibited) the several mountain grades of 2.2 per cent. not found on the other lines, and the increased mileage, more than off-set the advantages, although the latter were very important.

Referring now to the other two lines, the Assinniboine and the Dearborn routes it will be seen by the map (exhibited) that these lines come to a common point at the city of Spokane, and our comparisons will extend only that far for the present.

The Assinniboine line traverses the plateaus north of the Marais River, called Lonesome Prairie, crosses the summit of the Rocky Mountains through Marais Pass, descends to Flathead Valley by the middle fork of the river of the same name, climbs over the Kootenai range to the Kootenai River by way of Fisher River, follows the Kootenai to Bonner's Ferry in Idaho, where the river turns northward then passes through a wide gap in the Cabinet Range to the Pend d' Oreille River, which it follows to the east line of the State of Washington (where the river also turns northward) and then swings southward going down the little Spokane River to the vicinity of Spokane.

The Dearborn line crosses the Rocky Mountains at Roger's Pass 4 miles south of Cadotte Pass, spoken of in the Government reports, goes down the Big Blackfoot to Missoula and down Missoula River to the St. Regis de Borgia River, climbs the Bitter Root range by the way of this stream to the Sohon Pass described in Capt. Mullen's report on Military roads in 1863, thence down the Coeur d' Alene River to Mission,

thence over a divide via Fourth of July canon to Fort Sherman and thence across the plateau to Spokane.

Taking up now the points for comparison on these lines. The Dearborn route used about 150 miles of the already constructed line to Helena and Butte, about 100 miles of which runs through what has been up to the present time unproductive country. A stretch of about 150 miles of similar country is found on the Assinniboine line, so that, train service for a Freight Division is required for the Northern line, in excess of what would have been needed for the Dearborn route.

For the second point relative distance was slightly in favor of the Northern or Assinniboine line.

For the third point it is proper to consider only what would be the ruling grade for a freight division, regardless of helper grades and also the number of helper grades, and their rate of grade. The Assinniboine line gave one division of 1 per cent. and two of .06 per cent. in either direction, while the Dearborn gave line 1 per cent. on all divisions but one. There are three helper grades on the Northern Route, with grades of 1.5 per cent. and 1.8 per cent. against six on the Dearborn route of 1.7 per cent. and 2.2 per cent. counting helpers in both directions. The Dearborn line gave 35 miles excess of helper grade over the other.

Fourth: Rise and Fall considered only where depressions are too great to be treated as velocity grades, shows a difference of 500 feet in favor of the Assinniboine line.

Fifth: In alignment there appears to be about sixteen full circles in favor of the Assinniboine line.

Sixth: Resources. The Assinniboine line being on a lesser elevation for a greater number of miles shows more favorably for agriculture, although the country is now sparsely settled. The lines were about equal in grazing and timber resources. In mining, which is always an uncertain factor, there appeared to be greater possibilities in the Libby Creek, Lake Creek, Kootenai and Pend d'Oreille Districts on the Assinniboine line than in the single Coeur d'Alene District on the Dearborn route.

Seventh: Climate. Both routes show a snowy region extending over a distance of fifty miles. There is probably an excess in rainfall on the Northern line.

Eighth: The disadvantages in regard to operation on the Northern line have been spoken of in the first point of comparison.

Ninth: The Dearborn line is only a few miles north of the Northern Pacific Railroad for fifty miles east of Missoula and for a distance of 150 miles west of that city, it practically parallels a branch or branches of that road. The new towns along the northern route will, without doubt, equal in importance those along the already occupied territory, with no probability of a division in business.

Tenth: In construction features the Dearborn route gave three miles in tunnels and an excess of bluff work along rivers, while the total length of tunnels by the northern route was only 4,400 feet. In bridges over large streams there was not much difference. Although the mileage to be constructed by the Dearborn route was 150 miles less, the estimated cost for grading and bridging was slightly in excess of that for the other route. In summing up all points for comparison there appeared to be a large difference in favor of adopting the Assiniboine line.

Taking up now the line from the Eastern boundary of the State of Washington to Puget sound, I will first refer to the question of the terminus.

There was one possible terminus not on the shore of Puget sound, viz: Portland, Oregon. The extension from Butte via Lewiston, Idaho, was the only line which led to Portland. The difficulties on this line, previously spoken of, were sufficient to cause it to be discarded, but there were others of considerable importance, as for instance 200 miles along the lower Columbia River, one side of which is already occupied by the O. R. & N. Ry. Co.; the occupation of the territory between Lewiston and Wallula by three lines of railway; and the construction of two long and expensive bridges over the Snake and two over the Columbia, the four estimated to cost over $2,000,000.00. The character of the line therefore caused the rejection of Portland for a terminus.

Puget sound gives about 100 miles of almost continuous harbor from Tacoma northward, and the place for the terminus depended largely upon where the Cascade Range was crossed, as it was evident that the line must get down from the Cascade summit by some one of the river valleys. Generally there is a town or a harbor with a place for a town near the mouth of each stream. The Snoqualmie led down to Seattle, or Everett (not in existence in 1890.) The Skykomish led down to Everett and the Skagit led down to the famous Fidalgo Island, Anacortes City, one of the early selections for terminus of the Northern Pacific Railroad: it also had an outlet at Bellingham Bay by a swing to the northward. The city of Fairhaven, on Bellingham Bay has been said to have the best harbor in the sound. In 1889 Larrabie and Bennett and their associates had built 26 miles of road, the Fairhaven and Southern from Fairhaven to the Skagit. These parties may have thought that some transcontinental road would come down the Skagit and fail to find Bellingham Bay, or they may have thought that with 26 miles of constructed road on the western end, it would be an easy matter to fit in several hundred miles to the eastward.

I am quite certain that the passes at the head of the Skagit had never been carefully examined at the time this road was constructed.

It is not the first time that a terminus has been located on the coast and a line run to it afterwards. The Great Northern purchased the F. & S. R.R., and it forms a part of a line along the Coast between Seattle and the Terminus of the Canadian Pacific Railway. The line from the east could tap this Coast line at the most favorable point and the official terminus could either be at such junction, or at the nearest suitable harbor, or at an existing city, as the Railway Company might dictate. The N. P. terminus on the sound being at Tacoma, and the Great Northern reaching tide water at some point north of this place, should the latter's terminus be as near as possible to Tacoma, or as far as possible to the North? I will leave the question unanswered. Seattle being the largest place on the sound, whatever city may be the terminus, that city is certain to have the most business for some time to come.

Referring now to the lines across Washington, as previously stated the Northern route turned southward after leaving the Pend d' Oreille River to Spokane. It was possible to get a line across the country with quite a direct course from the Pend d' Oreille at Newport to the mouth of the Spokane River, and thence down the Columbia to the mouth of the Methow or to Lake Chelan. This line would have been 26 miles shorter than to go to Spokane and then run down the Spokane River. The grade for this shorter line would have been 0.4 per cent. heavier, and the business of Spokane, a town of 25,000 people would have been lost. This Newport cut-off was only available in case some pass at the head of the Skagit was found to be favorable. It would have necessitated building more than 100 miles along the Columbia, much of the distance in canon, and with a difference of from 40 to 50 between high and low water, the cost of construction would have been extremely heavy. A line down the Spokane and Columbia Rivers would have been devoid of local business, there being only a half dozen Chinamen's shanties in the whole distance of about 180 miles.

As compared with a line through Spokane and crossing the plateau south of the Columbia, (The Big Bend Country,) and using any of the passes of the Cascade range south of the Skagit waters, the Newport line is longer, being 32 miles longer than the adopted line, via Steven's pass and the Skykomish to Everett.

With the question settled as to going to Spokane and crossing the plateau west of that city, the problem is reduced to that of the physical features which can be generally understood from the profiles of the various lines upon which I have shown the elevations and grades of all the available Cascade Passes (Profile exhibited.) The adopted line shows the shortest distance, the least rise and fall, the lowest summit at the crossing of the Cascades, the least curvature, the shortest summit tunnel and the cheapest construction. It also gives

the most favorable place for the construction of a temporary line to be used during the construction of the summit tunnel, which will require not less than 2½ years time. The adopted line crossed the range through a pass discovered in 1890 by Mr. C. F. B. Haskell and named for Mr. J. F. Stevens in charge of the explorations. Among other passes examined were the Rainy, approached by Methow River, the Cascade, approached by Lake Chelan, and the Indian and the Cady approached from the east by the Wenatchee River; Nason Creek, a branch of the Wenatchee, runs down from Stevens Pass.

In crossing the plateau west of Spokane the line follows the drainage of Crab Creek thereby escaping the Grand Coulee, a chasm ½ to ¾ of a mile wide 900 feet below the level of the plateau. A more northern line would have been obliged to cross this chasm requiring 2.2 per cent. grade to climb out of it, and also the same grade to make the descent to the Columbia River, whereas the Crab Creek route uses 1 per cent. in making a descent 900 feet less, and avoids the intervening summit.

I will close with a few words about the difficulties attending this work and the rapid construction. Four hundred and thirty miles out of a total of 818 miles were in heavy timber. Along no part of the distance was there a road, and for nearly 200 miles no trail. The transportation for all surveys was by means of pack animals. In several stretches of primeval forest the accumulation of fallen trees made a progress of five miles a day on foot in exploration sufficient for the most energetic and strongest men. In making a reconnaissance of 35 miles near the Rocky Mountain summit an engineer starting out with blankets and six days provisions on his back was without food four days, and, after recruiting, became lost in trying to return over the same route. He finally succeeded in making the round trip at the end of thirty days. Although the Marais pass was looked up in the United States examinations of 1854, the pass then found was 20 miles north of the one used by the Great Northern and was 2,400 feet higher.

The reconnaissance was quite thorough and condensed profiles from barometric heights and estimated distances were made. The original barometric profile of the Assinniboine line on which I have marked the actual profile of constructed line shows several river crossings, and summits of grades, within one mile of their position as by surveyed mileage, and at elevations differing from true elevations by less than 50 feet. Spokane, distance estimated, is less than 5 miles off, with the accumulated errors on 512 miles. (Profile Exhibited.)

The first explorations started by me were in December, 1889. Some country on the Dearborn route had been looked over by Major Rogers, in 1887.

The first preliminary surveys on the adopted line were begun in

March 1890 and grading was started in August of the same year. Track laying was begun October 20th, 1890, and completed January 6th, 1893. 556 miles of main track were laid in 1892, and the track laying force was idle about three months of the year. The track gang was not stopped for unfinished grade after March, 1892. The best day's work at track laying was 4½ miles. The Two Medicine bridge, a wooden structure 212 feet high and 800 feet long, containing over ¾ of a million feet of timber, was built in 45 days. About 5 million feet of timber were put into structures by one firm of contractors in less than two months.

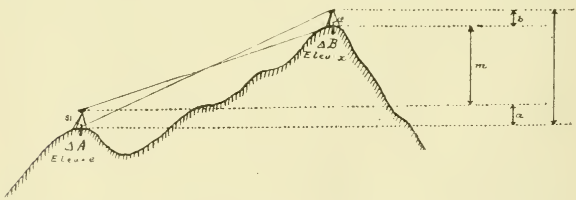
REDUCTION FORMULA FOR STADIA LEVELING.

By J. L. Van Ornum, Member, Western Society of Engineers.

[Read March 1, 1893.]

In accurate topographical surveys in hilly and mountainous regions it is necessary to secure correct elevations of the stations occupied by the field instrument, which differ much in altitude. Distances in broken country and vertical angles of large degree being often necessary the transit and stadia furnish as a rule the most advantageous field equipment.

Closed lines are run to check the lines both for measurement of distance and for elevation. Two readings are taken on each course,—



on the station ahead stadia reading and vertical angle are taken (as well as azimuth angle) then this station is occupied and the same readings are repeated on the station just left. The horizontal components of the stadia readings furnish the true length of the courses. With the vertical components of these readings a double determination of the elevation of each succeeding point is made.

The process devised for combining these vertical components is as follows:

Let the elevation of station "*A*" (already known) be "*e*," the H. I.,

there be "a" and the vertical component of the reading on the next station be "m." Let the elevation of the next station—"B" (to be determined) be "x", its H. I., be "b" and the vertical component of the reading on "A" be "n." Represent the correction for curvature and refraction by "c."

A moment's notice of the diagram will indicate that the *true* elevation of "A" and "B" (considered in connection with back-sight and fore-sight) should be represented at the distance "c" above them, or at "s" and "t":—so that, in the case represented, on the fore-sight "c" should be added and on the back-sight it should be subtracted from its vertical component.

The following equations, then, are derived:

(1.) $x = (e + a) + (m + c)$ [by F. S. from "A."]

(2.) $x = e + (n - c) - b$ [by B. S. from "B."] whence

(3.) $2x = 2e + m + n + a - b$ [by adding (1) and (2),] or

(4.) $x = e + \frac{1}{2}(a + m + n - b)$.

If "B" is lower than "A" the signs of "m," and "n" are changed in the discussion and the result is similar.

Equation (4) gives the form of reduction used, which is seen to cancel the correction for curvature and refraction in the computation. Errors due to the instrument being in not perfect adjustment and to heat affecting the bubble tube or other portions of the instrument (which is often quite troublesome) both being errors of a character similar to that due to curvature in their mathematical effects, are likewise eliminated. So that the only errors entering the result are those of observation and non-vertical rod. Such errors when large are at once detected on the reduction of the vertical components and can be corrected in the field. Also by this method of reduction all errors are *halved.*

The elevation (of the station) being thus obtained, the elevation of instrument is found by adding to this elevation the Height of Instrument at the place. This gives the elevation used in deducing the elevation of all secondary points taken from the station.

Results obtained by stadia survey, with the increased accuracy of elevations secured by the use of this reduction formula, are very satisfactory and therefore very useful in permitting important surveys to be made in less time and at less expense than with older and more tedious methods securing the same accuracy.

Note:—It will be noticed that I have used the term "H. I." to refer to the Height of Instrument above the point in question, and "E. I." (Elevation of Instrument) to denote what is ordinarily termed Height of Instrument, viz.—its elevation above the datum. This usage I have found necessary to prevent confusion of terms, and the more rea-

dily adopted it as it is a correlative term to "Elevation" in expressing reference to the datum plane.

DISCUSSION.

Prof. Ira O. Baker. I regret that the author is not present to answer questions. The diagram indicates that he measures his vertical angles to the surface of the ground, and it would be interesting to know how he computes the horizontal and vertical "components" for this case. Apparently it would be simpler to measure the vertical angle to a movable target set at a distance from the foot of the rod equal to the distance of the line of sight above the point or "plug" over which the instrument is set, in which case both *a* and *b* will vanish from equation (4.) The paper assumes that the correction for refraction is the same at the two stations, which is not strictly true. The paper states that closed lines were run to check horizontal and vertical distances, and of course azimuths too. Can not the Secretary secure from the author data on the degree of accuracy attained by him in such work?

Mr. T. Appleton. In Mr. Van Ornum's paper on stadia Leveling, he uses the phrase "Height of Instrument" to designate the height of the axis of the telescope above the ground or point of observation. For the past fifty years "Height of Instrument" has been universally used to denote the height of the axis of the telescope above Datum. The system of keeping level notes has long been known as the "Height of Instrument" system, to distinguish it from the old "Plus and Minus Difference" system. It may be that the words "Elevation of Instrument" as suggested by Mr. Van Ornum more clearly express the height of the instrument above datum, but the old meaning has become so firmly rooted and so well known that it would be unfortunate to give the phrase a new significance. It would be better to select some other phrase, snch as "Altitude of Instrument," or "Axis Height," for instance, for the height of the telescope above ground, and leave "Height of Instrument" to mean the same thing that it has for so long a time.

Mr. Van Ornum. Concerning Professor Baker's discussion I would state that the diagram was drawn merely to illustrate the formula, and not to indicate all details of the field work. In actual practice the vertical angle is always read to the point of the rod at which the stadia-reading is taken and the reading of the rod denoted by the middle hair (at the same angle) is entered in the notes. This stadia-reading is reduced to its horizontal and vertical components and the "reading of the rod" just mentioned is then added to or subtracted from the vertical component according as the angle is one of depression or of

elevation. Were the angle not so taken a considerable error would enter into the work when the angle is large, 30 degrees or more at times.

The suggested advantage of a moveable target set at a reading equal to the "H I" would simplify the computations when this could be done. But because the stadia distance must be read to the point to which the vertical angle is taken, sights would necessarily be limited to about 900 feet in length (the lower half-interval of the ordinary transit generally covering its height at this distance.) This fact would frequently make a target so used impracticable, as there is at times a necessity and frequently an advantage in taking longer sights. The length of courses on the International Boundary Survey has averaged more than 900 feet.

Refraction is assumed equal at both stations because, even in extreme cases, its difference would hardly affect the vertical component in the third decimal place.

I had omitted giving data of results obtained so far on this survey because I expect to more fully discuss them in the report I shall make to the Commissioners when the survey is finished. However I may say in general that thus far on over two hundred miles of line run by the four topographers since the adoption of this method the average error in the closing of levels has been about $^1/_{40,000}$ of the distance *per degree* of vertical angle; the general ratio of error to degree of vertical angle holds quite constant whether the average angle be one-half degree or fifteen degrees. The accuracy could be still further increased did the vertical circle read closer than to minutes, and by working only in fair weather.

The use of the transit and plane-table for topography, now rapidly increasing, make necessary the adoption of terms (1) for the elevation of the telescope above the datum plane, and (2) for the height of the telescope above the station. To apply the term "Height of Instrument" to the former is plainly a mis nomer. If former usage of the term is to govern, as Mr. Appleton suggests, it will not only perpetuate the unfortunate expression as it has been used in level work, but will cause confusion in other fields where "H. I." has also been used to express the latter term. It seems an opportune time for Civil Engineers to fix these terms; these I have used are the ones that seemed most logical.

FREEZING OF THE WATER IN A SUBMERGED PIPE.

BY DEXTER BRACKETT, MEMBER, BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read May 17, 1893.]

The following description of an incident which occurred during the past winter in connection with the Boston water supply may be of value as an example to some one in similar circumstances.

Between Moon and Long Islands in Boston harbor, there was laid in 1888 a line of 6 inch flexible jointed pipe about 3,400 feet in length. These pipes had the well known Ward flexible joint in which the bell of the pipe is turned in a spherical form, and the ball is formed by the lead, which is held in position by two collars cast on the spigot end of the pipe. The channel crossed has a depth of about 15 ft. at low water and the shore on either side has a slope of about 3 ft. per 100. In order to protect the pipe from the action of the waves the pipe was laid in an excavated trench from high water mark to a point where the water attained a depth of 10 ft. at low water. The trench was excavated about 2 feet in depth and the pipe, which had been previously laid on the bottom, was then rolled into the trench and covered. About 1,500 feet of the pipe in the deepest portion of the channel was not covered by the earth.

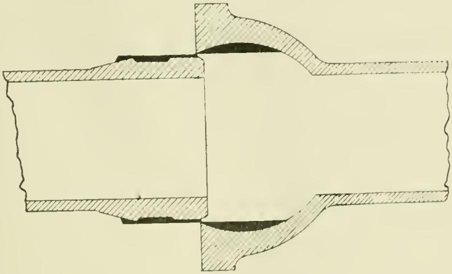
This pipe was laid in 1888 and had been in use without accident until January 15, 1893, when the water stopped running and as there was very little draft through the pipe, and the weather was extremely cold, it was supposed that the water in the pipe might have frozen near the shore, between high and low water mark where the pipe was not deeply covered.

On examination, however, the pipe was found to be free from ice at the shore ends but was apparently frozen in the middle of the channel, and this was afterward proved to be the fact. In March when the pipes were taken up, long pieces of ice were found in the interior of the pipe. The cause of the freezing of the fresh water in the pipes is quite clear when I inform you that the temperature of the salt water in the harbor was found to be but 28 degrees.

On examination of the pipes by a diver, it was found that some of the pipes were broken, which was to have been expected, and also that in a considerable number of cases the joints had been pulled apart,—that is, the spigot end of the pipe was pulled entirely out of the bell and the lead was sheared off, leaving one portion of the lead in the bell and the other portion on the spigot end of the pipe as shown by the

sketch. This was somewhat unexpected, but was probably caused by the expansive force of the freezing water. The water became frozen at two points 10 or more feet apart, and as 11 feet of water makes 12 feet of ice, the freezing water acted as a hydraulic jack and forced the pipes apart.

When originally laid each pipe was covered with a boxing of 3½ inch plank and the space between the pipe and the boxing was filled with a grout of lime and cement to preserve the pipe from the action of the salt



water and sewage, all of the sewage of the city being discharged near the point where the pipe is laid.

The pipes, when taken up, showed that the covering had afforded a perfect protection and there had been no rusting except in a few places where the bells were exposed.

The pipes were taken up in lengths of 24 feet and where they were not broken or pulled apart by the ice, they were expeditiously cut or broken by the use of small charges of dynamite. On account of the boxing with which the pipes were covered, the dynamite could only be placed very close to the bells of the pipes and yet in but a very few instances were the bells of the pipes broken, the spigot ends being fractured close in front of the bells.

MANAGEMENT OF MODERN STEAM PLANTS.

BY R. BIRKHOLZ, M. E., MEMBER WISCONSIN POLYTECHNIC SOCIETY.

[Read June 12, 1893.]

Some Judge said that there were three kinds of liars, one kind being the modest deliberate liar, one kind the mean G-dd-d liar and the third kind the expert. I wish to scratch nobody. I myself have at times been classed an expert. You know how those fuel experts, agents of boilers, grates, self stokers etc., come to us to guarantee a certain per cent. of saving by using their appurtenances. When they are allowed to put them in, they generally do the firing themselves, or direct it, and they usually superintend the trials of evaporation. And if other experts are selected for that work, how easy is it for the polite and gentlemanly agent to get the so called disinterested expert to help him a little. Should the agent attempt to bluff the expert, he could easily slip in a little extra against him. Generally the saving is effected by good, careful and scientific firing.

A Magdeburg factory had twelve expert firemen to fire successively. Coal and Water were weighed and there was as much as 30 per cent. difference in the results. At the Pabst Brewing Company, Mr. Pabst, highly interested in his steam plant, caused us to introduce a system, which is now quite perfected, although we had much discomfort with it in the beginning. It is a plain system, devoid of experting, a system which shows not only the work during some hours of careful firing, but which shows the actual work done by the firemen each month, spurring the foreman fireman to do still better by getting a special reward for an evaporation effected higher than a fixed normal amount. We simply put in a Worthington Hot Water Meter into the boiler feed pipe. The meter is of brass. In the beginning the meter showed an evaporation of 8 pounds of water per pound of coal in the continuously fired boilers. Month after month the evaporation decreased, I watched the fireman, told him he must do better, still the evaporation ran down thus per month: 8, 7.45, 7.32, 6.65, 6.13, 5.80, 5.35, 5.20, 5.20, 4.62, 4.37. Then I had the meter tested and found it very much worn out by the exceptionally sandy Milwaukee Water Works Water. Our feed pumps cut out very quickly on account of the sand. I tried to withhold the sand by large settling tanks, still the pump plungers cut. By opening our cold water main pump, I found the eddies in the valve chambers completely filled up with sand, which clotted together as if clay was admixed. The coal we use is an inferior grade, mixed slack, giving 18 to 20 per cent. of ash, which accounts for the low evaporation.

Our boilers are plain tubulars 66 in. × 18 ft. with 64-4 inch flues. Near the meter the feed pipe is enlarged and a high grade thermometer is inserted into a glycerine bath, and readings taken each hour. At the months end I get the thermometer book and the book with daily readings of meter. Frequent readings of meter and thermometer are taken and recorded in a book kept in the boiler house. When we found the meter so unreliable we improved the arrangement by purchasing another meter and inserting it after the regular meter, which we had repaired and re-adjusted. Now each month the latter alone is at work until the last day, when the by-pass is closed, having cut out the secondary or test meter for all the month, and for 8 hours the water having moved through the regular meter, is made to run also through the test meter. Readings are carefully taken and the percentage of incorrectness of the regular meter is ascertained, the quantity registered by same is corrected by me. It is interesting how the regular meter decreased in accuracy per month. The regular meter showed an evaporation thus: 8, 7.33, 7.54, 7.27, 7.60, 7.65, 7.66, 6.40, 6.80, 6.20 and the test meter showed: 8, 7.63, 8.17, 8.17, 8.85, 9.22, 9.55, 8.64, 9.04, 8.50. So you see, firing and keeping the boilers clean has improved on account of constant watching. The meter lost about 4 per cent. per month of the first reading, which means less than 4 per cent. of the preceding month, except of the first. In the beginning the meter began to leak rapidly, but the more it was worn the percentage of increase of leak became less, the difference in the last two months amounting to 3.008 per cent. The reason is evident.*

The evaporation I recalculate to standard from and to 212 degrees Fahr., taking in account the weight of water at the average temperature. As this metering goes on for a whole month, day and night, and as readings are written down each twelve hours, it is not easy for the man in charge to "monkey" with the returns. We can be quite sure of the results. We also weigh the ashes and know monthly which coal respectively—which mixture of coal at its price affords the best economy. As a matter of curiosity, I herewith state that our daily consumption of coal in May amounted to 95 tons, our daily evaporation 760 tons, or 133 gallons per minute, equal to about 4 barrels of water per minute. As we use much coal dust, considerable necessarily falling through the grates, the percentage, 19, of ash is high.

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* In ten months the meter lost so much as to reduce the evaporation figure from 8 to 4.62 in one case and in the second case the meter lost in 10 months as to reduce the figure of evaporation from 8 to 6.20. You want to learn the reason of this: The meter used in the first case was of less than half the capacity of the meter used in the second case. It is always to be recommended to use rather too large a meter than too small a one, as the motion of the register pistons is quite slow in case of the large meter and thus the wear is low.

We use the McClave and Brooks' Scranton Shaking grates for small coal. Of our 24 boilers, we have 17 working, each one evaporates per hour, 3680 lbs., which is about 1000 lbs., less than the boiler can do with good coal, and per square foot of grate we burned per hour 15½ lbs., which is also low, it could be 50 per cent. higher with good coal. Now, one thing has to be considered, when new boilers are put in, the test of evaporation is taken as soon as possible. Boilers are then yet clean inside and outside. If new firing arrangements are applied to old boilers, the test is made, if conducted by the seller of the firing arrangement, after the boiler is cleaned very scrupulously inside and outside. And as a boiler of a certain heating surface, must have a certain grate surface to work best, and as the plant has to be be fired up to a certain capacity to show best results, the experts crowd the plant for a few hours and let the steam, generated more than used by engine, or other machinery blow-off, thus maintaining a praiseworthy evenness, and regularity is always a great factor of economy. As breweries use steam very irregularly, we have tried to guard against irregular draft of steam from boilers by putting in a 33 inch steam pipe of about 250 ft. length to afford storage. Our average evaporation per year was 8.57 lbs., water, the coal if yielding only 10 per cent. of ashes instead of 20, as good Pittsburg coal does, would thus evaporate 9.43 lbs., of water in average of 360 × 24 hours. Sometimes the boiler will evaporate 5000 lbs., of water per hour, burning 22 to 23 lbs., of coal per square foot of grate, sometimes considerably less, not only during noon hours, or Sundays, but also throughout the working hours, owing to the irregular use of steam. When experts show an evaporation from 11 to 12 lbs., of water with good coal and scientific firing, with even evaporation in new and clean boilers, we are perfectly satisfied with our results.

ELECTRICAL STREET RAILWAYS.

By C. F. Uebelacker, E. E., Member, Civil Engineer's Club of Cleveland.

[Read April 11, 1893.]

The subject of Electric Railways is so wide and can be discussed from so many points of view that an address condensed into a short space of an hour must necessarily be somewhat incomplete and sketchy in its character.

The ordinary method of procedure in papers of the character of the present one is, I believe, to attack the subject first from historical point of view. History of this special class is, however dull, and un-

interesting to those not immediately interested in the profession. Accordingly I will pass over this portion of the subject with a single remark, that it is but five years since the first commercially successful electric road was installed at Richmond, Virginia, while at the present day there are in this country alone thousands of miles of street railway operated by electricity. I have not the slightest hesitation in stating that the United States stands far in the lead in electric railway matters, both in mileage of track at present operated, and in the completeness and practical adaptation of apparatus to the conditions as existing. With this brief statement of the past and present position of the electric railway, let us pass to a general consideration of the functions and requirements of the street railroad of to-day, for it is in its application to street railroads that electricity has become prominent in so short a time.

The functions of the street railway can be all, or nearly all, brought under two principal heads. First:—An opportunity for the investment of capital. Second:—A convenience to the public and aid in bettering the condition of the middle and lower classes without appreciable change in the present ratio between their earnings and expenses.

I can readily conceive that the order of importance in which I have placed the two main functions just mentioned, is liable to be questioned by many. A discussion of the question would, however, consume much space and be decidedly out of place under the present heading. (I will content myself with this one defense of my arrangement, namely, that putting the convenience of the public before the rights of investors, would be a decided step toward the paternal form of government, or toward the principles of communism.) We will then assume for present purposes the order as given, and proceed to consider the requirements governing the choice of a method of operating, and the results of the introduction of a street railroad. The principal points required of the equipment might be summed up as first, low cost of operation, second, accomodations such that the patronage of the road will steadily increase, and third, with the patronage the value of property. It is necessary to remark that with the present financial methods low cost of operation is more than ever a necessity, and in low cost of operation must be included low first cost, as the interest upon both bond and investment should be charged up as part of the operating expenses. Incidentally it might be of interest, at this point, to state the present methods of procuring the necessary funds for the equipment of a street railway. The ordinary method of procedure is to form a company, procure the desired franchise, and then to bond the road for nearly or quite, the complete value of the equipment required, and often of the franchise as well. These bonds, can generally be disposed of at a few per cent. below par, where the franchise has any

appreciable value, and by their sale the cash required for the equipment and starting of the road is procured. This is a very convenient method of funding, but carries with it the disadvantage that these bonds must bear at least 6 per cent. interest on their face value, which 6 per cent. must be charged up in the operating expenses of the road and paid before dividends can be declared.

The *results* of the indroduction of street railroads are widely beneficial, especially, as before stated, to the poorer classes. This and the succeeding remarks of course refer more properly to city roads in distinction from suburban roads, or roads which depend for their patronage upon traffic between towns.

The first result in order of prominence is the tendency toward the reduction of the population per square mile in the residence portion, greater areas being brought within reaching distance of the manufacturing and business portions of the city, reaching distance at all times being estimated not by miles but by time. The immediate results of this spreading out tendency is the reduction in the value per square foot of land accessible for residence purposes by the laboring classes, due to a greater area being brought into the market. As a consequence of this reduction air and light are more plenty, sanitary conditions are better, and the general health of the population must necessarily be improved. Facilities for buying are also increased, the markets where food is sold fresh and cheap are accessible to the women with the baskets whom we meet so frequently on the cars Saturday evenings. As a result of this improvement in the sanitary conditions of homes, and in food we are certainly justified in expecting an improvement in both physical and moral development of the laboring classes. It is my belief that the results before enumerated, namely, the reduction of the population per square mile, the increased comfort of the homes, and the effort to obtain supplies from the centres where prices are low and middlemen are few, can already be plainly traced in the cities where urban rapid transit has been introduced by electric and cable railways. Probably this very city of Cleveland presents as good an example of the tendencies enumerated as any in the country. It seems to me that we have only to look at the small neat homes which have already been built, and are at present in course of construction, along the street railway lines to realize that a new era is in store for the laboring classes in their domestic arrangements. If any one will take the trouble to follow, say the Superior Street Cable Road, or the Central Ave., or Wade Park lines of the East Cleveland road and investigate the conditions existing along the side streets in their immediate vicinity, he cannot help but be struck by the neat and homelike appearance of the cheap comfortable buildings there found.

Another very marked result of the introduction of urban roads is

the rise in the value of outlying property rendered accessible by them. Property which has been previously suitable for the residence only of those who could command time and independent means of transportation is brought within twenty or thirty minutes ride to the busiest parts of the city. The value of the ground appreciates from 20 per cent. to 50 per cent. and sometimes even doubles. Farms are immediately cut up into building lots, small houses spring up, and within a year or two at the most we find on what was previously farm land a thriving settlement.

A slight decrease in the city taxes may also be looked forward to, owing to the receipts of the city in the rental for streets and privileges granted to Street Railway Companies. This rental may take numerous forms, paving and percentages of receipts being at present most prominent, and the former probably the most useful, saving as it does in many instances the issue of bonds by the city.

Country roads, or properly speaking, inter-urban lines are governed by slightly different conditions, the principal differences being the necessity of lower cost and higher speed. It is here that electricity has, and is, destined in the future to be adopted most widely. The small cost of construction will enable projectors to push their lines much more widely with electricity that with any other equipment.

These country lines, traversing as they do districts distinctly rural, foster communication at seasons of the year when roads are well nigh impassable, or when traveling by the ordinary means is unpleasant. With the increase of communication comes an attendant increase in trade, and also that education and knowledge of the world which can be gained only by frequent communication with the centres of civilization. These roads also furnish facilities for cheap and rapid transportation to and from the cities at all seasons, thereby cheapening and bringing into the households of the country the conveniences and luxuries of the city, and bringing to the city cheaper and fresher the food products of the country.

Having now hastily glanced over the functions, requirements, and results of the introduction of Street Railways, let us look for a while at the means with which we have already achieved these results and propose to extend our achievements in the future. In this connection an almost endless list of schemes for the propulsion of vehicles might be brought up, but we must confine ourselves under the subject chosen almost entirely to the consideration of electric means. Let us glance first at the general mechanical requirements of a system for the propulsion of vehicles. In the order of their importance I would name the principal ones as follows:

1st:—Speed.

2nd:—Control.

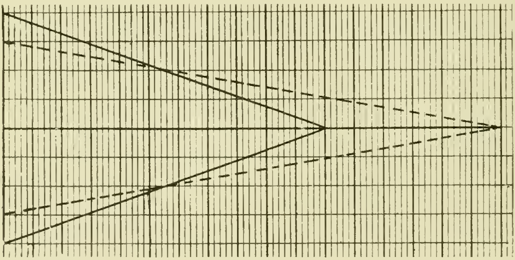
3rd:—Economy of repairs and reliability.

4th.—Economy of labor.

5th:—Economy of first cost.

6th:—Economy of power.

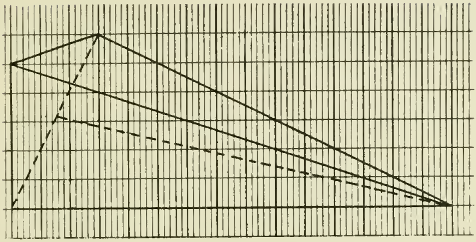
In speaking of *speed* we must refer at all times to average speed, *i. e.* to the speed obtained by dividing the schedule time from one end of the route to the other, into the distance run. Under present conditions this speed varies between the limits of eight and twelve miles an hour. With the weight of cars and means of controlling them in use, this is about the limit which can be used with safety in public streets, as long as stops are made as frequently as they are at present. An increase of speed will, of course, increase the area reached in a given time. I think I can make this result plain by the aid of a diagram which you see on the board.



SKETCH 1.

It might be interesting, for those scientifically inclined, to note that if the line of track be taken as the axis, the tangent of the angle formed by the line bounding the territory rendered accessible, with this axis would be the average speed attained by a pedestrian divided by the average speed attained by the car. It must be remarked, however. that this deduction, although rather pretty scientifically, is in practice rather thrown out by the tendency of the human race "never to walk when they can ride." A vast majority greatly prefer to ride twenty minutes rather than walk ten. This tends to lengthen out the wedge formed in the manner illustrated by the dotted lines. Despite these objections I think, however, that this principle can be made useful in deciding upon the location of lines if applied in connection with the proper study of the habits of the population being accommodated.

On this same sketch given above we might base an estimate of the value of property along a proposed line in the following manner:



SKETCH 2.

The perpendicular distance of sloping surface from plane in which track lies is proportional to the value.

The second requirement, namely that of *control* has been placed in the position of secondary importance advisedly. It governs directly, in connection with the degree of carefulness used by the employees, the yearly quota of accidents. Increased speed entails poorer control, which, in turn, increases the number of accidents. We must balance against this increase of accidents the advantage before mentioned of increase in property values, better sanitary conditions, and pleasanter homes. Let us balance once the value of life taken from the pecuniary standpoint against the rise in the value of property. To assume that the average man earns $1000 a year would be placing a high value upon his services. We will, however, make an estimate upon this assumption together with the assumption of 5 per cent. interest, $1000 is 5 per cent. upon $20,000. This $20,000 may then be considered as the pecuniary value of one man's life. Should life be sacrificed this $20,000 lost must represent interest upon an increased value of property in order that the two sides of our ledger may balance properly. A balance of this kind would give one accident per year for every increase of $400,000 in the value of property. We would then on a purely pecuniary basis be justified in sacrificing one life for each $400,000 advance in property. We have not, however, taken into consideration the improvement in the moral and physical condition of the population due to the possession of more comfortable and desirable homes. It strikes me that this consideration should bear great weight even though it entail occasional sacrifice of the life or limb of an individual.

Requirement three, that of economy of repairs might frequently change places with the next item succeeding, was it not that economy of repairs and reliability necessarily move hand in hand. Reliability is a question of the utmost importance, involving as it does the confi-

dence of the public and consequently their patronage. This consideration fixes the item of repairs fully as high in the list as I have placed it, and I doubt not that many a road manager out of the depths of sad experience would recommend its occupying the first position on the list.

The fourth condition, that of economy of labor owes its importance to the necessity of general economy for the production of dividends. Labor is by far the largest item of expense in the running of a road, and is accordingly the one which we first seek to reduce as far as possible. Economy of labor is of two kinds, first the number of employees required to operate the road must be small, and second the apparatus must be of such a character as to be readily handled by men who do not command the wages of skilled laborers.

Economy of first cost is, of course, desirable in order that the road may cover as much territory as possible without necessitating large outlays upon which to pay dividends. It would hardly be desirable to enter upon the discussion of actual costs at this point. It would require the introduction of too many statistics and would hardly be interesting to this audience. Suffice it to say that electricity has undoubtedly the most economical system both in cost of construction and in cost per car mile run. It has no competitor but the cable, the first cost of which is high and its action not so reliable, due to the whole road depending upon one movable member (the cable) for its power.

Requirement six, that of economy of power is important both in cutting down running expenses and in reducing the first cost of the equipment required. It is, however, by far the least important of the requirements we have mentioned and as such we need not discuss it further at present.

Having then reviewed the mechanical requirements which our apparatus must fulfill, let us consider the adaptability of electricity to these conditions, beginning with the apparatus for the conversion of electrical into mechanical energy at the car, taking up next the apparatus for transmitting of energy, and finally that by which we convert mechanical into electrical energy at the power station. The conditions to be fulfilled at the car are as before noted, speed, control, economy of both labor and power and reliability. To gain a high average speed two things are requisite, a high maximum speed, a quick start, and a quick stop. The latter depends upon the braking apparatus which, being purely mechanical, can be applied the same to all systems, and need not be considered here under electrical heading. The maximum speeds ordinarily in use vary from twenty to twenty-five miles an hour, and it is doubtful if these will be much exceeded in city practice, owing to the numerous stops required. This leaves us the question of quick starting to consider. Let us first examine the law by which the

motion of a car must be governed. We will find that this law is approximately the ordinary law of acceleration governing the motion of all material bodies and expressed by the formula

$$T = \frac{W \times V}{G \times F}$$

Where $T =$ the time in seconds
$W =$ the weight in pounds
$V =$ the velocity at the end of the time T
$G =$ the acceleration of gravity in feet per second, and
$F =$ the accelerating force applied in pounds.

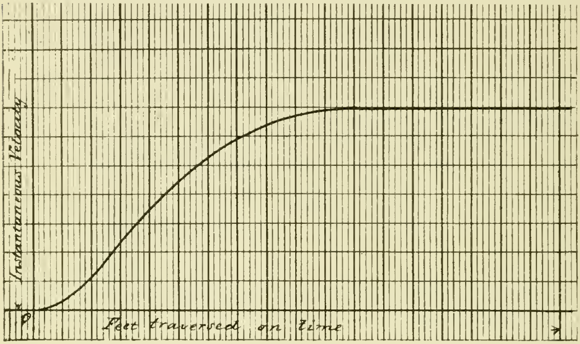
In applying these quantities to the problem in question T will become the time in seconds required to reach a velocity in feet per second of V.

W will become the weight of the car, its equipment, and load. And F will become the drawbar pull or thrust on the rails at the circumference of the wheels.

This formula is, of course, only approximately true as it considers the motion as frictionless and due to a constant accelerating force F. It is, however, approximated by the conditions under which a street car works, provided that we leave out the consideration of friction. It points out to us two things, namely, that if we desire to obtain a high velocity in a short time our car and equipment must be light, while our accelerating force or thrust at the circumference of the wheels must be large. Let us now branch off and look for a moment at the actual conditions under which a car gains its speed. It starts very easily: then for a moment it gains speed so rapidly as to give almost a jerk; from this time on until it begins to approach its maximum speed, the gain in speed is fairly constant. As it approaches nearly its maximum speed this rate of gain of speed or acceleration falls off gradually until speed finally becomes steady. Plotting these conditions in graphical form we get this curve. See sketch 3.

From this curve we discover that the motor must give, in order to follow the conditions laid down, a strong torque or thrust at the circumference of the wheels and the slow speed while starting and during acceleration and on attaining the maximum speed required must give a low torgue and a high number of revolutions. Glancing at the graphical representation of the action of what is technically known as the series wound motor we will find that it naturally tends to fulfill these conditions exactly. The torque or pull given being in inverse proportion to the speed. What it lacks in this direction, is completed by the arrangement of the controlling apparatus, which places it in the power of the motorman to govern the speed of running and the speed of starting, and the direction of running of his car.

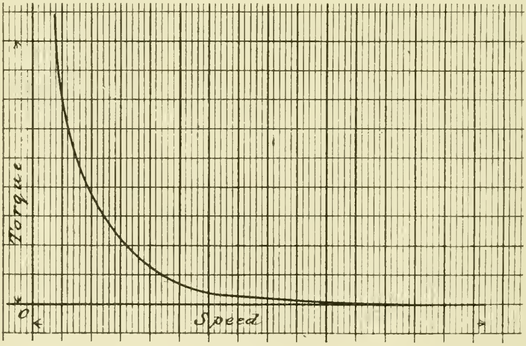
The principal requirements of the line are efficiency of transmission and reliability. These could not be more admirably combined than in



SKETCH 3.

a stiff, straight, immovable wire consuming no energy, when not transmitting any, which is the form assumed by the transmitting device for the electric road.

Coming then to the generator, or the apparatus for converting mechanical into electrical energy for transmission, we find that the conditions above stated require that it be reliable, efficient and cheap. The

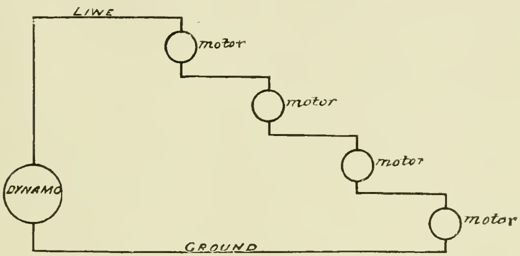


SKETCH 4.

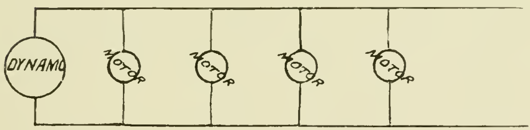
present arrangement of generator and its equipments are fully as reliable as the power that drives them, and more need not be said. In economy the generator is beautifully fitted for the purpose required,

automatically regulating the power generated to meet the demands of the power required by the cars.

Having now examined the suitableness of electric power for the propulsion of street cars, let us look into the arrangement of the system by which this agency is employed. This system is best demonstrated by the water pipe analogy, which will serve to explain all the principal points although it is by no means perfect. In this analogy the dynamo would be represented by a pump, the line wire upon which the current is conveyed would be represented by a pipe, while the motor would be represented by a water-wheel or turbine of some description. The size of the pipe would correspond to the size of the wire required, the pressure put upon the water would correspond to the voltage or potential difference generated by the dynamo, while the amperes or



SKETCH 5. SERIES SYSTEM.



SKETCH 6. MULTIPLE SYSTEM.

volume of the current would correspond most nearly to the amount of water forced through the pipe.

Sketches 5 and 6 show the two arrangements which have been used for the connecting in of street cars in this system. They are known, as marked, as the Series and Multiple system. The Series system in which the current remains constant and voltage varies according to the requirements of the cars was one put in use early in the history of the application of electricity to the propulsion of vehicles. Its advantage was a great saving in the amount of wire required to convey the current. This was off-set, however, by the very complicated ar-

rangement of switches necessary, and this system has been discarded almost universally for the Multiple system in which Voltage is constant and Current varies, represented in sketch 6. There are three general plans upon which stations have been arranged. The first was the earliest and involved the connection of the engine to a jack shaft from which the dynamos were driven by friction clutch pullies. This was necessitated by the small size of the dynamos employed at that time. The second arrangement, and one which is still in use almost universally, was that of belting the dynamos directly to the engine pullies, and came into favor as the size of the dynamo was increased. The third and latest arrangement, and one which undoubtedly will be universally employed in the near future, is that of connecting the revolving portion of the dynamos directly to the end of the engine shaft, giving it a speed of revolution the same as that of the engine. The only valid objection to this last requirement is that the dynamos must be larger and heavier for the same out-put if their speed of revolution is slow enough to match that of the engines now in use.

The lines for transmitting the energy to the motors are erected in two ways. First by placing a pole upon each side of the street, and stretching between them a span of supporting wire from which the trolley wire is hung over the centre of the track, or by placing poles along one side of the track and supporting the trolley wire upon brackets reaching out from these. Either way is good if thoroughly constructed.

In order to ensure the continuous operation of the road, the line is constructed and connected to the stations in sections so that should any one portion become disabled, traffic on the remaining portion will not be affected. This division is accomplished by placing insulated joints in the trolley wire. Such joints are only noticable to the initiated, by the momentary darkening of the incandescent lights in the car when the trolley wheel passes over one at night.

As mentioned before in illustrating the action of the electric system by the water analogy given above we depend on the track and ground to furnish a return path for the electric current after it has passed through the motors. This necessitates a new departure in track construction, namely, that of ensuring a good electrical contact between successive rails. This (bonding as it is technically termed) is accomplished by riveting to the adjacent ends of the rails a piece of copper or iron wire which thus bridges the joint formed by the fish plates by which the rails are bolted together, and ensures the electrical connection should the bolts and fish plates of the rail joint become rusted.

Of the many questions asked for the sake of general information, that which is most frequently proposed to the technical man is probably, is electricity capable of supplying the necessary power to operate

the large trunk lines of the country, and, if capable, will it ever supplant the steam locomotive? As far as capability of supplying power is concerned, there can be but one answer, and that is that the electrical power developed is only limited by the mechanical power which drives the Dynamos.

The second question, however, we must touch more cautiously. The efficiency of the electric system of propulsion, and I speak now only of the commercial efficiency or the ability to pay a percentage on investment, is highest where a great number of trains are despatched at short intervals, as in street car work and at the best several trains must be dependent on one station and one line while each steam locomotive is an independent unit. On the other hand we can say for the electric motor that it is less liable to injury, is cheaper to build, requires less skill to operate, need not stop for water and coal, takes less coal for the power developed, and can in virtue of its motion being primarily rotary and balanced, develop with safety under the same conditions a slightly greater speed than the steam locomotive whose motion is primarily reciprocating and at best only indifferently balanced. The limit of safe speed for either locomotive or motor is, however, limited by the condition of the ordinary track to speed far below that which the locomotive can attain with safety.

The Electric Railroad is only eight (8) years old. Already it has made its appearance in most of the best paying localities and spreading out into more doubtful fields. There is at present great activity in the construction of suburban and comparatively long lines. These are beginning to handle freight, express, and mail. One great step is still to be made, *i. e.*, production of reliable and efficient Alternating Current Railway Motor and System. The Alternating Current is better suited to transmission to great distances. Aside from the this main principles bearing on construction are pretty well understood, and the future advances are most to be looked for principally in the line of perfection of details, increasing reliability, and decreasing cost.

PRELIMINARY SURVEYS FOR A RAILWAY LINE.

By James Ritchie, Member Civil Engineer's Club of Cleveland.

[Read June 13, 1893.]

The writer has in charge a projected Railway, in the surveys for which some methods have been employed which may be of interest to the members of this club and to Engineers in general, there being some deviations from the long established practice in this kind of work.

The proposed line extends from the harbor of Fairport on Lake Erie

about three miles from the City of Painesville, Ohio, to a station on the line of the N. Y. L. E. & W. Ry., known as Phalanx, about 46 miles from Cleveland, said proposed line being about 46 miles in length, intended eventually to be continued to Youngstown, about 20 miles further south-east.

The object of the road is to provide another line for transportation of coal and ore to and from the Lakes, with such local business as may be developed along the line. The great point to be considered, was to obtain as low a grade as possible with the least expenditure of money, and with as direct an alignment as could be obtained.

The first difficulty met with was the Lake Erie bluffs, which extend along the lake for its entire length, intersected and crossed by streams of the nature of the Cuyahoga, Chagrin, Grand and Ashtabula Rivers, which form deep valleys, but which are so tortuous in their course, that the idea of following them for their entire length is certain to greatly lengthen any line, and thereby increase the expense of construction as well as the cost of operation. These streams have also many falls, which would necessitate sudden changes of grade, and prevent the maintaining of a low ruling gradient. This is especially true of the Grand River, at the mouth of which is the Harbor of Fairport.

It was therefore necessary to start out with a heavy grade from the lake, intending to use a helping engine to the first summit from which point one engine could haul the maximum train.

This summit is near Chardon, about 12 miles from the lake. The heavy grade can be operated in two ways, either by using a pusher on the maximum train, or by having the terminal yards at the summit and taking the cars up and down by yard engines as they may be loaded, and making up the maximum train at the summit. The latter, is probably the method that we shall adopt.

In October and November 1892, a preliminary chain survey was run from the lake to Phalanx, and the profile showed that a grade of $26^4/_{10}$ feet per mile could be obtained between Chardon and Phalanx, although the line surveyed being only a preliminary, did not give any information outside of its own territory, excepting what was obtained by barometric observations taken in connection with it.

The best grade that could be obtained north of Chardon was 66 feet per mile, and this could not be obtained except by deviating from the surveyed line.

The writer has been connected with several railroads, and on each one has endeavored to introduce the stadia method for preliminary surveys, but has always been met by the prejudices of his superior officers, who did not believe in the method, or had never tried it, and hesitated to do so.

In this work, it was decided by the writer to use this method in all

surveys after the first preliminary, but, in deference to the wishes of his associates, one line as above stated, was run by the old method. This was a good means of comparison also for cost and results.

It having been determined by a barometric reconnoissance that the best line would be found by way of Chardon, Burton, Troy, and Nelson townships, and through certain valleys therein, a survey by stadia was made, the topography of each valley carefully determined and maps platted as shown herewith.

To those unacquainted with this method of topographical surveying, it may be well to explain, that it is the method used by the U. S. Engineers in filling in the topography between their points of triangulation. In this survey, there were no triangulation points, but our first preliminary line served as a partial check upon our work and the results satisfied the writer that the Stadia Survey was fully as accurate as the chain survey.

The best method of making a stadia survey is to occupy each stadia point, orienting the transit by setting the supplement of the forward angle upon the last station and turning off each sight to the right, reading the vernier from 0 deg. to 360 deg., without transiting the instrument. This was adopted in all cases excepting on one line, which was surveyed as a line connecting two stadia lines and on which alternate stations were occupied, and the orientation performed by the magnetic needle, setting the 0 of the circle on the magnetic meridian. The sights were then taken to the rear and forward, and the results have more than equaled the writers expectations; as the greatest variation from the preliminary chain survey at points of intersection was 20 feet in distance while the direction has never been appreciably out. The levels were carried on by the vertical angles, checking on the first preliminary as often as possible, the greatest error being three-tenths of a foot.

The reductions were made in the office by the use of Johnson's Tables, the main stadia points being reduced in the field so as to enable the necessary checks to be made as the work progressed and to see that the general level was in conformity to the desired grade.

For a description of the general theory of stadia surveying the members are referred to Johnson's work on Topographical Surveying by Transit and Stadia, which fully and clearly describes the method and gives the tables, our only variation being that one of our stadia lines is a very carefully run compass line, instead of a transit line.

On the maps made from the stadia survey we have platted a location, and have made a profile of said location, which is fully as accurate as could be obtained in the field, and for an estimate of cost is far superior to any preliminary profile.

This line can be reproduced on the ground by careful measurements,

and the writer feels very confident, that, except for the obstructions which right of way matters may cause, the line located from this map, will show a profile and alignment the same or nearly the same as is shown on the profile made above. This line is about one mile longer than the first chain survey or about 46 miles.

In locating from this map, there will be no backing up and changing, or running new preliminary as is always the case under the old way, but we can reproduce this line as it is, without delays, or we can change it in the office as we may desire before attempting to locate it in the field.

The chain survey of 45 miles occupied 24 days, and the stadia survey of 46 miles in length, and averageing about 800 feet in width, occupied 30 days, three or four of which were stormy in part so as to delay the work greatly.

The estimate of earth work on the line plotted from stadia survey is 1,341,508 cu. yds. or 30,000 cu. yds. per mile average, being calculated as all excavation and borrow, the necessary corrections being made for side hill work as shown by the contours.

The points determined by the survey are generally as follows:

1st. All main stadia stations and side stations for extending topography.

2nd. All buildings, fences, land-lines, roads, creeks, top and bottom of banks, and any knolls, changes in slopes, or points which would indicate a change in shape of the contours, all these points being determined by the rod reading, horizontal angle and vertical angle, giving the distance, direction and difference of elevation from the point of observation.

The recorder makes all necessary sketches marking the points observed on same by letters, and using the same letters in his notes.

The stadia party consisted of a chief, a transitman, recorder, and four or five rodmen.

The location first plotted was not entirely satisfactory to the writer, although it gave a very good profile, but several changes in alignment have been made on the map, greatly reducing the curvature without materially affecting the work of construction. Another advantage is thus shown for this method of surveying, as no location work in the field will be commenced until the location shown on the map is satisfactory. It will be interesting to compare the profiles taken from the map location with that obtained by the field location, and that will still further demonstrate the usefulness of this method of surveying, or will show that it is not what the writer claims it to be, the most satisfactory method for preliminary surveys in a difficult country.

DISCUSSION.

MR. CULLEY:—I wish Mr. Ritchie would explain the method of taking topography.

MR. RITCHIE:—You have your transit pointed, and whenever you want to locate anything you send a rodman out to that point, and the distance, horizontal and vertical angle, are read from the transit, and sketches are made, and the points observed are designated on the sketches. One advantage of the method seems to me to be, you get a great deal more information for the cost, and such information that, when you locate your line, instead of running half a dozen preliminary lines in the field, we have run all preliminary lines on paper, and we know the location is right before we start.

MR. EISENMANN:—It was my good fortune to be associated with the pioneer of the stadia in this country, the late Mr. J. R. Myèr, Asst. U. S. Engineer, who, in 1848, came to this country a revolutionist from Switzerland. They had about finished the topographical survey of Switzerland, and there the stadia was used. In conversation with him he told me that it was surprising how accurately levels and contours agreed after the railroads went through that country. The method there in Switzerland was—it is a hilly country—primary down to secondary and tertiary triangulation, and the intermediate topography filled in by stadia work. Mr. Myer, soon after his arrival, was detailed with the College of Engineers who had charge of New York Harbor, and vicinity; from there he drifted in the early fifties to the United States' Lake survey with headquarters at Detroit, and became one of its chief topographers; in fact all topographers in those early days were European trained men. Their assistants grew up with the work, and after the requisition was made upon Michigan University for recorders, some thought was given to reproducing his articles in English. I think Professor S. W. Robinson was the first American who lectured upon that subject. I think that it was through Professor Robinson that Mr. Myer was induced to write a series of articles in the *Journal of the Franklin Institute.* He used the old formula of the stadia, in which the focal distance was practically eliminated. The stadia rod was graduated for an average distance to be used in the field, and any distance, longer or shorter, was either too large or too small, but within the limits of error allowed on surveys mapped on small scales. The first author, I think, that gave a correct formula, was a gentleman connected with the geological survey of the State of Pennsylvania, from which Mr. Johnson, in his book on the stadia, has compiled his tables. Mr. Myer's time observaticns were reduced with the aid of graphical plates, both for horizontal distances and vertical angles.

Mr. Culley asked a question about the method of surveys. Usually in a topographical survey, whether it is dependent upon a net work of triangles or independent lines, the salient topographical points are taken; the value of the stadia work depends entirely upon the accuracy with which you do your work. You can sweep over a large territory and take in everything within sight, half a mile wide, or confine yourself to a much smaller range and it will give you, particularly in a rolling country, more accurate results than the chain.

In 1815, in the survey of Lake Ontario, all the work done that season by the stadia was interconnected with the primary and secondary triangulation points.

Parties were requested to make their reports upon the accuracy of their stadia surveys between these points, and I think the average was only one in eight hundred. These reports were compiled in the Chief of United States Engineer's Report for 1875. The stadia workers were given a limit of error of one to three hundred. I have made stadia surveys repeatedly when the error was as low as one in three thousand, and that is more accurate than you can rely on with the chain, that is, over rolling ground. In nearly all the preliminary surveys I have made, I have adopted this method. In the absence of any measured triangulation or bases, select your stadia bases so that you can interconnect your stadia points as a continuous triangulation, read the angles from a full circled instrument, avoiding this right and left that is so confusing upon a railroad line. By double readings, *i. e.*, forward and backward, you will check any errors,—in the elevation eliminate the refraction, and also the error of the circle.

MR. CULLEY:—In 1872 I was on the preliminary survey of the Ashtabula, Youngstown & Pittsburgh Railroad. We used the old method of taking topography. I was transit-man and topographer in that location and construction. When we got to Warren we struck Red Run. It is a crooked stream running to the south-east of Warren. The Ashtabula Railroad was located along this run. When we got east of Warren the engineer struck, what they considered, difficult topography. The old method of taking topography was to measure out to houses, etc., and sketch in the topography. The hills, ravines, etc., were sketched in. The line one and one-half miles long, was such that it could not be seen from one end to the other. My impression is, we were two months trying to get a satisfactory location. I was a "kid" at the time, but concluded to embody the several surveys in one map, the survey parties having run lines on both banks, up and down the stream, probably to the extent of twenty miles of single line. When thus made I drew on the map a straight line for the location. Getting topography together in that way gave us means of determining a satisfactory line. Had the method here presented by Mr. Ritchie been used,

one survey would answer for all; it would have taken in both banks of the brook.

This winter I was called to Olmsted Township to test the alignment of a line five miles, or some 26,000 feet long. I wanted some method to get across the township very quickly. I conluded to use the stadia. The line was located at one end by monuments some 1800 feet apart so I was sure not to get far away from it, at the other end not more than 150 feet at the farthest. If I varied ten feet in a thousand in length it would not affect the off-set. Length observations were taken by stadia and afterwards compared by actual measurement. I was very much surprised to see the close agreement between actual and stadia measurement. In no case did the stadia vary more than one foot in 2,000 feet.

I would like to speak of the method that was used in determining a straight line on railroad work in my experience when a trial line was made to reach a given point.

In my experience of twenty years ago we used what is called picket lines, leaving a quick approximate line at small expense. (Illustrates on the blackboard.) Mr. Ritchie said something about chain survey. I suppose the chain was a band chain. Modern railroad surveys are now made with the band chain. The old chain is obsolete.

Mr. Ritchie:—This chain survey was done with the old chain, so it would appear obsolete to Mr. Culley.

Another advantage of the stadia is this: all the accurate work that requires care is done by one man. In the chain survey there are two chainmen who have to be pretty careful. If they are not careful there is trouble. They may drop 100 feet, or hold the chain slanting; whereas in a stadia survey one man at the transit does all the work. Of course, the recorder has to keep his notes right; but it does not make so much difference what the rodmen are. You can have ordinary laborers, almost.

Mr. Cook:—I know of an instance in which the stadia was used in making railroad survey by an engineer named Burlington. I do not know how the work was carried on, but I saw the maps and profiles.

Mr. Paul:—I have been very much interested in Mr. Ritchie's very full account of his surveys, in which the details are very clearly taken and satisfactorily represented. For the expenditure incurred he has certainly given a very clear picture of the country which he has traversed, more so than by what is called line survey. I have had some experience in preliminary survey with railroads, and am satisfied that there is, perhaps, no direction of engineering work which is ordinarily attended with as little satisfaction as preliminary survey. There are several reasons for that state of things, which do not necessarily affect it from an engineering stand point. These surveys are often of

a temporary character. A great many people are satisfied if they have a line run between two points, and the quicker this is done, and the more miles traversed in a day, and the sooner the parties disband the better they are satisfied. If some one takes up his survey in the future, the chances are that such maps and profiles convey very little information as to the ground traversed.

Mr. Culley spoke of a person being transit-man and topographer. In my judgment, one person cannot fill both these places at one time. If it is attempted, as it often is, the important work of topography must suffer.

I have had some experience as topographer, and believe that a good one may often, by supplementing their work, accomplish more than the other dozen or fifteen men in the party. He may and ought to be, the eyes, and sometimes the ears and fingers of the whole party; not because he is a better engineer, but because it is possible for him to gather and preserve results which would otherwise be lost, and put them in such shape that they may be used.

One great advantage I can see about the stadia method is, the ability to depart from fixed lines. An engineer, in making a line survey, gets as near the ground that he wishes to occupy as possible. By using the stadia he can skip around more freely and need not make his survey on the line which he wishes to occupy at all, and thus save trampling of grain and cutting of timber.

Another thing which comes up in every day practice of re-surveying railroads, is that the ordinary method of taking the angles and measurements, however accurate they may be, often gives very unsatisfactory results, and mere fractional accuracy is not all that is needed. A combination of stadia and plane-table methods would enable an engineer to depict surrounding features of the country probably in one-fourth of the time, much more satisfactorily. An objection I can see which might easily be urged is the temptation to too much elaboration and the danger of accumulating too much useless data. While paper locations are useful, and indeed well nigh indispensable, still I do not regard them as finalities. I think the time of the engineer should be largely spent upon the ground, and results reduced to paper from day to day and made available: otherwise errors of paper location are certain to accumulate, especially in a very rough country. Much of the map-making may be done on the ground itself, or from day to day, and thus save the keeping of elabarate notes.

Mr. Eisenmann:—I take exception to the remarks of Mr. Paul about the transit-man not being a topographer. That is where he mistakes. The topographer is the brains of the whole party; he directs the rod-men, and the recorder records it.

Mr. Paul:—In the ordinary line method the transitman has all he

can do. Mr. Eisenmann does not understand me; we do not disagree. What I mean is that if a transitman must be a topographer, he must have some one to keep his notes.

Mr. Eisenmann:—I have had as many as four stadia men to one recorder. We go along the field, the transitman directing, the recorder recording, and an assistant plotting in the details on the ground, so everything is in pencil, and then the location of an improvement is all studied out in the office. You can go over the whole country without a dollars worth of damage. When a map is once made, if it is correct, you can pick it up at any time, whether the stakes appear or not. On the continent of Europe surveys are made on large scales, if you want to draw a location of a road, you go to the department and get the maps and sketch on your road, and then go and lay it on the ground and find it will be within the limits of error. The government has made its surveys with such care and accuracy. In certain parts of this country, particularly the Mississippi Valley, surveys are made on a sufficiently large scale so that, if you get the original maps you can make a location for an improvement of this kind, whether it is a roadway or a railway or anything.

Mr. Culley:—I take exception to Mr. Paul's remarks. I find in my own practice in surveys that it is better to put the preliminary surveys on paper and then after a careful analysis place it on the ground. Make your map in the office before final location.

Mr. Searles:—Circumstances alter cases. Both sides of the discussion here to-night are right, in their way, I think. When we refer to European methods and the United States' Coast survey, we find the stadia is an excellent auxilliary to the more exact method of triangulation, the latter forming the true skeleton while the stadia work fills in and completes the picture. I have never felt as though the stadia work was well adapted to original surveys, or any in which there was not at any rate, a check upon it by some independent survey. It depends upon what you want. A great deal of discussion here has been upon the question of paper location. In many forms of topography I consider this extremely important, because it is the very best way to do it. In other cases it is less so. A paper location can be made from a correct topographical map without any stadia work; and this has frequently been done with great success. So the question narrows down to this: how advantageous stadia work is in the preparation of the topographical map for the purpose of the paper location of a railroad line. Now, the several preliminary steps of locating a road are: a reconnaissance with or without instruments; a preliminary survey of some sort, followed by a map of the same, a projected line of location on the map with its profile, and, finally, the actual location on the ground. The older method was, as has been hinted here to-night, to

blunder ahead and make the locations somehow on the ground without any map, and many roads have been so located; and years afterward, when they could afford it, they have been re-located; whereas, if the work had been done on paper before attempting to do it on the ground, the probability is that re-location would not have cost more than one per cent. of what it finally cost.

If the reconnaissance is carefully made so that the engineer is tolerably sure of where the located line ought to be, he does not care very much about the topography right and left of that line to any wide extent; and then the method becomes simply driving a preliminary line on that fixed route, and making the width of topography just enough to include the work that is to be done in grading, or possibly show the effect of the road upon the neighboring property. But if the country is broken and rolling, then I think the stadia work comes in very favorably, and gives us a wider range of view in making selection of our location: at the same time we lose something in precision on any one part of the line.

I have a feeling that in locating topography simply by points, viz: where the rodmen have stood, that much of the intermediate work was indefinite, and although it appears definite on the map, it is, to some degree, inaccurate, So that where your projected line runs intermediate on the map between two stadia stations, the profile is likely to differ quite a little from the final profile, or from the reality obtained on the ground. We have not here the test of this. I am sorry for it. It would be quite interesting to test the accuracy of these particular maps before us to-night by the location map and profile, when they are perfected. My impression is, with all due respect to the gentlemen interested, that when the located map is completed, this preliminary will be relatively worthless. That is to say, location being made by chain and transit with the usual care, topography sketched along the projected line will be found to differ to such a degree from the reality, that these maps will be cast aside in favor of the new ones. My preference has been, as might be inferred from the remarks made, to study the ground itself carefully first, perhaps without instruments, so as to know very closely what I want to do and then confine the work of the party to that line. In that way I have avoided using the stadia, although I have no objection to it. It gives very good topography which often proves to be far outside of the right of way of the railroad. Theoretically it is a bad way to survey, because the triangles are so ill-conditioned. The legs of the triangles are several hundred feet long, and the base is only a part of the stadia rod. The part intercepted on the rod is so small compared with the distance from the instrument, that if there is any error in the reading it becomes wonderfully magnified in its results on the distance.

I was running a transit line high upon a bluff, too steep for vegetation yet so you could hang onto it with your teeth, and I came across a deep gulch emptying into a bay, the bottom of which was nearly down to water level. To get across that by ordinary chaining was going to be a very slow process. Although we were not exactly prepared for stadia work, I conceived the idea of triangulating across the gulch by using a level-rod for base line. A rodman was sent across and established a point at random, and that rod was observed by two cross-hairs that happened to be in one of the instruments. I am not sure that the hairs were set for any particular scale or purpose, but there happened to be two. When I had opportunity later, on a level piece of ground, I undertook to send the same rod from the instrument until, by trial, the rod should take a position where this same distance on the rod would again be intercepted between the same two hairs; and we then measured the distance; but to be satisfied that the distance was somewhere near right, I sent the rodman again—he not having marked the point—to repeat the operation, and we measured by chain the distance between the instrument and rod. We found a discrepancy of twenty-five feet in the two measurements. It struck me there was no great accuracy in the method. The fault may have been in the man or instruments; but on general principles it appeared that while we may observe small distances on the rod with considerable accuracy and apparently small errors, I should not like to undertake to locate points by inversion of the method, *i. e.* by observing the rod and motioning the man backward and forward until a certain reading on the rod was gotten. I would rather chain directly or triangulate for it. It is surprising how good results we can get from stadia work, notwithstanding the fact that a few inches on the rod are multiplied into as many chains in horizontal distances. But for auxiliary work I think it is an excellent method.

I am very glad that we have had this example in our neighborhood, and presented to this meeting; but I shall look with interest to the verification of the whole method by the comparison of the location line on the ground with that which has been made on the paper. I am not so sanguine as the author of the paper, that no changes will be necessary in repeating this line on the ground from the indications given on the paper. I have never seen any preliminary, however carefully made, that did not require some correction on the location notes when you came to put them on the ground.

MR. THOMPSON: In an open country not much wooded it would be useful in filling in topography; but in a mountainous country where the timber is heavy, and close together, and the ground much broken, a great distance on either side of the line is not required. You are generally obliged to follow the gulch through, as in the Allegheny

Mountains for instance, and the stadia method would be tedious, and in a measure unsatisfactory.

Speaking of paper location, our method was to take topography in the ordinary way with slope levels or other hand instruments. The level-man himself was expected to give much attention to the topographer, and be able to answer every question except such as belonged especially to the transit. The location line is projected on the map of the preliminary line, on which the topography is drawn, the profile of the preliminary line being of course considered. I have, in exceedingly rough country, thoroughly wooded, seen location checked inside of one foot in a distance of a mile. As the item of cost is a leading factor in the construction of railroads, the location is often, in thickly settled districts, made secondary to the question of right of way.

Mr. J. F. Brown: I have been using the stadia some in the past two or three years in running random lines, in rough country for locating a line; that is, in measuring a random from point to point over the knolls or hills. I ran one random 3,800 feet long last summer, and I measured the distance with the stadia rod, and summed up the total; and after checking over the true lines by actual measurement there was only a difference of $^{13}/_{100}$ of a foot.

I also measured some dock lines where it is difficult to span the distance, and those distances have been carefully computed by the city engineer. I have tested some of the points, and I find on distances of from 500 to 600 feet the stadia will read down to within $^{3}/_{100}$ or $^{4}/_{100}$ of a foot of actual distance. I am satisfied that the stadia is more correct than the actual measurement for that kind of work. I can depend upon it, and save a great deal of time; and I have tried it in various ways. Running random lines 3,500 feet long you save, by using the stadia, half the work. A job which would take two days can be done in one day more easily than in the old way.

I have used that method of work a great deal in cemetery work. I run a system of lines and connect the stations with transit and steel tape; run a line of levels on the station points, and make a skeleton and go over it with stadia, and I find results pretty close.

I never undertake to establish grade lines with the stadia; I think it is risky. I know a young man who, last year, undertook to use the stadia in making contractors' estimate, and he reduced our estimate 50 per cent. The proprietor asked for a comparison. We produced our cross-section sheets and the level-notes, and asked for the young man's figures;—he had a lot of stadia notes. I refused to compare with him; he evidently had made some errors. I laid the paper to one side and notified the proprietor that when the figures were presented in proper shape I would compare with him. I never heard of it since.

I think as a general method for outline work for getting at

topography, the system is excellent and cannot be beaten

Mr. Culley: Mr. Clemens Herschel delivered a very interesting paper on civil engineering before the Boston Society of Civil Engineers, some time ago wherein he said that all engineers were surveyors. This is true only in a general sense; but when it comes to municipal surveying all engineers are not surveyors. We find in our experience on municipal work, where measurements have to be made with the utmost accuracy, that railroad engineers, as a general rule, are no good.

Mr. Ritchie: In railroad work we find that ordinary city surveyors are no good, for they will measure things down to $^1/_{100}$ of a foot, where it is no earthly use to measure nearer than 10 feet; they are precise, but use no judgment in their selection of the time for precision.

Mr. Culley: The remark was not made as a personal one and the point was not made as such; but I can corroborate Mr. Ritchie's statement by men who have been brought up in this city. As a rule work measurement to the nearest foot is good enough for railroad work: but municipal work that is measured to the nearest $^1/_{100}$ foot is good.

A problem originated in this city to determine the inter-section of two rights of ways of difficult width; one on a curve and the other on a tangent. I presented the problem to an experienced railroad engineer and asked him how he would determine the point? He said "I take my chain and get a center line point on one railroad, and measure out the distance from that center line to the outer line of right of way; do the same with the other road, and that would give you the point." (?)

Mr. Porter: In preliminary work we must not always think that the only object in view is to save money. I understand that the use of the stadia is to get the most information that is possible for the money expended. There is a certain amount of money to be used for making a preliminary survey, in a certain length of time; and the problem is to get the most information possible for this money. I have always thought the chances for error in stadia work were too large to warrant its use in accurate work. I almost think so still. But there are cases where the stadia gives large results for small expenditure, both of money and of time.

THE CHICAGO RAILWAY PROBLEM.

By Thos. Appleton, Member Western Society of Engineers.

[A Continuation of Discussion. Read June 7, 1893.]

About a year ago a Committee of this Society appointed to investigate and report upon "The Railway Problem of Chicago in relation to Terminals, Rapid Transit, Marine Commerce and Related Interests," made its reports. These reports indicated much careful investigation and contained many valuable suggestions. The recommendations were mainly general in character, as would be expected in a matter affecting so many interests. The discussion which followed the presentation of the reports was not as voluminous or as far reaching as such a subject deserved.

The purpose of the present paper is rather to re-open an investigation which seems brief and incomplete, than to claim intrinsic value for its suggestions.

While the Committee's report bristled with statistics regarding lake marine commerce, the figures for railroad traffic were very meagre. In Mr. Corthell's minority report, he says:

"In 1889 there were received and delivered four and one quarter millions of freight cars, making the daily handling nearly twelve thousand cars. There were moved over forty-three million tons of freight. There were over eighteen million passengers moved over its main lines, and on its suburban lines nearly eleven millions." This refers to the business of the city of Chicago. Without doubt the average daily number of freight cars moved in 1892 exceeds twelve thousand. I cannot give the number of passengers moved during the past year, but from recent time tables I estimate that on week days there are not less than 270 through passenger trains and 740 suburban trains, not counting the World's Fair special service trains, making a total of over 1010 passenger trains daily, in and out. This with the 12,000 or more freight cars daily makes a total daily car movement that is truly enormous.

It is unnecessary for me to repeat to you, gentlemen, the words of the Committee regarding the terrible list of casualties occurring upon the railroad tracks of this city, nor to allude to the expense and delay caused by grade crossings. Hardly a week passes without a terrible example of the street crossing fatalities. All citizens recognize the evil of operating railroad and street traffic upon the same level, and all, whether they are railroad officials, aldermen or ordinary citizens, are seeking a remedy.

The majority report of your Committee does not recommend any

hard and fast rule of universal application for accomplishing the separation of street and railroad grades, but after enumerating several methods says— "Your committee does not believe it to be consonant with practicability or sound public policy to prescribe any one of the methods here outlined, for all the railways entering the city, or for all portions of any one line. The conditions existing along each, and varying on different portions of the same line must all be studied and that mode of construction resorted to which will afford the relief sought with the least outlay of money and the smallest damage to public and private interests. Any wholesale attempt to revolutionize immediately the existing condition of things would result in such an increase in the fixed charges of the railroads that the public would, as a consequence, suffer in its material interests."

Mr. Corthell's minority report says: "Your Committee can see but one plan that is practicable, and that is to at once adopt the principle and rule of raising the railroad tracks to a suitable height above the streets, and to cease the unsystematic and ill-advised method of raising the streets here and there, by means of viaducts of great cost, occasioning great damage to property and converting an otherwise level city into one of abrupt undulations. We would suggest, that, in order to avoid the construction of an elevated railway for *each* of the railroads, they should be combined into three groups of elevated railroads, one entering the city from the south and southwest, one from the west and one from the north."

After the Committee of this Society reported, the Commission of experts appointed by Mayor Washburne made its report on the matter of railroad terminals in this city, recommending that all steam railroads should elevate their tracks within the city limits, and that all their tracks should be entirely removed from the district bounded on the north by Kinzie Street, on the west by Canal Street, and on the south by 22nd. Street.

What reasons led this Commission to select these boundary lines, that on the north being immediately across the street from the North-Western Railway Station, and that on the west being adjacent to the Union Station, both commodious and costly structures, is not clear, unless the intention was to remove the tracks a sufficient distance from the river so that the streets could descend from the high drawbridges and pass under the proposed elevated railway tracks. Nor is it clear whether the Commission intended to include the tracks of the Illinois Central Railway in the list of tracks to be removed from the forbidden territory north of 22nd. Street.

A station at 22nd. Street would be one and three quarters miles from the Post Office; at Canal Street half a mile, and at Kinzie Street three quarters of a mile from the same point.

It would be a great mistake to force the passenger stations as far back as 22nd. Street. No street car line or rapid transit railroad could take care of the crowds of passengers that would be compelled to debark nearly two miles from their places of business. The steam railroads should deliver their loads of freight and passengers just as near their final destination as possible, in order to avoid congestion of streets. Five hundred trains each way daily receive and discharge their thousands of passengers, the greater portion of whom are destined for the business center as they come in in the morning, or departing from there in the early evening. The freight is distributed over a wider territory, although much of it, nearly all of the retail and jobbing business, comes into the business district. The 12,000 or more carloads of freight that are daily received and delivered should be carried in the cars as far as possible towards its destination in order to reduce the number of wagons and trucks in the already crowded streets.

The city is very fortunate in having its railroad stations so near the business center, and they should be maintained within a short distance of that center as long as possible.

More recently the City Council passed an ordinance known as the "O'Neil Ordinance" which requires that all steam railroads shall remove their tracks from the surface of the streets within a certain time. In one district the time limit is January 1st. 1895, in the second district the time limit is January 1st. 1897, and in the third district the time limit is January 1st. 1899. It permits the railroads to build elevated structures, excepting that these elevated structures must not be built longitudinally of any street. It makes no provision for raising the money for this work, and the City bears no portion of the expense, excepting that the Commissioner of Public Works is directed to remove, at the expense of the City, any viaducts that may interfere with the construction of the elevated railroad tracks. No provision is made for changing the grades of any streets, but it is specified that no part of the proposed elevated structure shall be less than sixteen feet above the established grade of the street.

It has been estimated that the cost of building a four track elevated railroad is very nearly one million dollars per mile. It would be difficult to say how many miles of track steam railroads now have inside the limits of this city, but it may be assumed at 800 miles. If single track elevated railroad costs $250,000 per mile it would require at least $200,000,000 to pay for the work contemplated in carrying out the provisions of the O'Neil ordinance. Even if the estimated cost is too high the amount of money to be raised to complete the work is enormous. And the entire expense is, by this ordinance, saddled upon the railroad companies.

In Massachusetts a state law has been passed to aid the abolishment

of grade crossings, by the provisions of which a portion of the cost of construction is borne by the town or city in which the grade crossing to be removed is located, a second portion is paid for by the State at large, and the remainder of the expense is paid by the railroad company. In the case of the great Fourth Avenue Improvement in New York, where the tracks of the N. Y. C. & H. R. R. R., were removed from the streets by constructing elevated or depressed tracks, one-half the cost was paid for by the City of New York, and street grades were changed to facilitate the work. Recently completed, and right within our City Limits is the great improvement made by the Illinois Central Railroad, by which its tracks were elevated above the streets, street grades were lowered under the bridges, so as to reduce the amount of elevation required and thus save expense, and a portion of the cost was paid by the World's Fair Corporation.

In any comprehensive plan for abolishing railway grade crossings of our streets the public has a material interest, and the City at large is benefited by the improvement; it would seem proper therefore that the City should join in the expense of the work, if not by actual cash contribution, at least by allowing changes of street grades to be made which would reduce the total cost of the work. By this ordinance the railroads are called upon to expend a vast amount of money, which does not add to their earning capacity. There may be a saving of expense in the maintaining of gates, wages of watchmen, reduction of damages paid for deaths and casualties, and an increased efficiency of service, by enabling trains to make better speed within the City Limits, and the improvement may carry with it an increase of facilities and conveniencies for the transaction of business.

Ordinarily a railroad corporation can borrow money for extensions or additions that will increase the business of the road, add feeders or enable them to reach new business, but this proposed elevation of tracks does not of itself add one penny to the gross earnings of any road. Truly it is outside the province of Engineering to say how the money for such an improvement can be obtained.

Under the ordinance the railroads must elevate their tracks at once or remove them beyond the City Limits, there is no compromise or concession, no alternative, peremptory elevation or absolute removal.

The sewer system has now been so far extended that it is practicable to make depressed streets or depressed railroads without any great difficulty. When the railroads were originally constructed in this City it was necessary to keep their roadbeds up out of the water, in order to maintain the tracks in proper surface. The same with the streets, they had to be raised above the adjoining prairie in order to keep them passable. Now it would be perfectly practicable to lower the railroad grades to some extent, and thus reduce the total elevation

required for the construction of viaducts over them or in the case of elevated tracks, the streets could be depressed somewhat and thus reduce the total cost of the elevated structure.

But the gross sum required for the construction of elevated or depressed railroads can be reduced by a consolidation of interests, and a relocation of tracks. The era of elevation should be proceeded by a period of relocation. It will cost less money to build two or three joint elevated roads, each with tracks enough to accommodate several roads, than it will to build a separate elevated structure for each distinct company on its present right of way.

Look on the map of this City. At Madison Street the business district has a width of about three quarters of a mile. At Twelfth Street the width from the Lake to the river is about three-eighths of a mile, but this width is practically reduced to the space between the tracks of the Illinois Central Railroad, and those of the Santa Fe Railroad, about three-sixteenths of a mile. During recent years the growth of the business district has been towards the South, threre are large retail stores and office buildings already built and occupied south of Van Buren Street, which but a few years ago was regarded as the extreme limit of the business district. The restriction of width caused by these railroad tracks and depots will prevent much further extension in that direction, and in other directions the business district is cut off from expansion by the River and the Lake.

To make room for the future growth of the business district the south branch of the river should be straightened out from Van Buren Street south along the quarter section line now occupied by the tracks of the Ft. Wayne Railroad, to 20th Street. Then the Dearborn Station and all the tracks of the Western Indiana and its tenant roads should be removed from the space east of Clark Street, the St. Charles Air Line should be removed east of the river, and the Lake Shore & Rock Island Station should be removed one block to the south. This would release a great deal of valuable land for business purposes, and the proceeds could be used in the improvements hereinafter named, and at the same time one of the worst railroad grade crossings in the world would be eliminated.

In the space between the relocated river and Clark Street, there would be room enough to construct a great Union Station fronting on Harrison Street, of capacity sufficient to accommodate all the roads which now use the Dearborn Station, the Lake Shore and Rock Island Station, the Grand Central Station and the Canal Street Union Station.

Perhaps the latter group of roads could be better accommodated in a continuation of this proposed station constructed on the west side of the re-located river.

With the exception of the two blocks lying between Sherman Street

and Fifth Avenue, Harrison and Taylor Streets, this land is now owned by railroad corporations, and the re-arrangement of tracks would allow of the land being used to much better advantage than as at present used.

The stations above mentioned, with the exception of the Grand Central Station, are already over taxed, and crowded beyond reason with their present traffic. There is no room for growth in their present locations, and the proposed Great Union Station could be used to advantage if constructed immediately.

The approach to this great Union Station on the south should be an elevated structure with sufficient tracks to accommodate the Chicago & Western Indiana, and its tenant roads, the Rock Island, the Lake Shore, and the Fort Wayne roads. On the southwest there should be another elevated approach to accommodate the Alton, the Santa Fe, the Baltimore & Ohio, the Wabash, the Grand Trunk, and the Panhandle roads.

The Chicago Elevated Terminal Railway, commonly known as the "Torrence Elevated Terminal," will when completed according to its ordinance, answer for the approach of all these roads to the proposed great Union Station.

The railroads now using the Canal Street Union Station could easily reach the proposed new station. These roads are pretty well equipped with viaducts for a considerable distance already.

From Lake Street to Polk Street these viaducts are as numerous as could be asked for. On the line west, used by the Northwestern, St. Paul and Panhandle railroads, three or four additional viaducts would give sufficient accommodation for street travel as far as Western Avenue. Beyond that street, elevation might be the best method of dealing with these roads. Between Fifteenth and Sixteenth Streets, west of the river, the space occupied by the C. B. & Q., Chicago & Northern Pacific and the Northwestern freight tracks, is pretty well provided with viaducts as far as Blue Island Avenue. Four or five more viaducts would finish up this district as far as Western Avenue, and from there on, elevated tracks might be used. A glance at the map, on which the viaducts are indicated by red crosses, shows that the viaducts are most numerous on the lines of roads running west from the Canal Street Station, and it seems a great waste of money to remove these viaducts, to which the people are accustomed, and to the grades of which their buildings have been accommodated, and make another change of street grades so as to allow elevated roads to be used. The Chicago and Northwestern road has quite a number of viaducts from State Street to Chicago Avenue, and it would seem unwise to disturb this condition of things by elevating the tracks south of Chicago Avenue.

The Chicago and Northwestern might also use the proposed Great Union Station, by following the south branch of the river from Kinzie

Street south, instead of crossing the north branch at Kinzie Street, using their present passenger terminals for freight purposes, although this is not essential.

The magnificent approach and commodious new station of the Illinois Central road might easily accommodate additional tenants after the World's Fair is over, and whatever roads concluded to use this station, would reduce the number of tenants to be provided for in the proposed Great Union Station.

Such changes of location as are here proposed cannot be accomplished without concerted action on the part of the railroad companies interested, and I recognize the difficulties that beset any such undertaking. The few companies having direct lines and ample accommodations at the present time are not interested in any change which takes away some of their property and turns it over to other less favored companies. The railroad tracks are here and we must keep them here; we cannot do without them, but the situation can be improved, and must be. Perhaps the matter can be most satisfactorily handled by the organization of a "Chicago City Terminal Association," as suggested in the majority report of the Western Society Committee: "To this Association the holdings of all the companies now having terminal property in Chicago to be leased upon an agreed valuation and the lesser companies to have representation in the management of the new Association. The Corporation thus formed to control and operate the properties acquired under its lease and also a centralized group of yards at, or near the city limits, which yards should become the Chicago termini of the several lines now existing, or to be built hereafter. Each road having a sufficient yard assigned to it. There all freight for Chicago should be turned over to the Terminal Association and delivered by it to city consignees at the yard or freight house nearest to the place of business of said consignee."

Perhaps it can be best attained by the promotion of the Chicago Elevated Terminal Co., or similar organizations.

The situation is surrounded with numerous difficulties, and conflicting interests, it requires heroic remedies. Any comprehensive or practicable scheme involves great expenditures, even partial solutions will be exceedingly costly.

The difficulties increase year by year, not only by the appreciation of real estate values, but by the natural growth of railway business, both freight and passenger, and the entrance of additional lines. Whatever plan is decided upon for the separation of street and railroad grades, the situation should be carefully studied in all its details. No money should be wasted in attempting to make, at this late day in the growth of this city, an ideal railway terminal; it should not be forgotten that four million dollars have been spent already in the construc-

tion of viaducts over the railway tracks, which sum ought not all to be thrown away, nor should we be deterred from adopting a really good plan because of the large figures which will inevitably appear when an estimate of cost is made. Compromise will be necessary and the projected plans should recognize existing conditions as well as future growth.

Before closing I would refer to some of the work that has already been accomplished by the several railway companies in the direction of improved terminals. The Illinois Central has built a new passenger station at 12th Street, has built new shops and yards at Burnside, and has eliminated all street grade crossings north of 67th Street. The Rock Island has built a large freight yard at Blue Island, and that is the terminus of all main line freight runs. The C. B. & Q., has a large yard at Hawthorne, which is the terminus of freight train runs. The St. Paul road is building a large yard at Galewood for a similar purpose. The Northwestern has a large yard at Grayland. with a connection to the Milwaukee Division at North Evanston. All these yards facilitate the distribution and transfer of freight so that a much smaller proportion of the total number of freight cars handled here, have to pass through the city. This is indicated by the constantly increasing business of the belt line roads.

It has been said that the railway situation could only be improved by some intelligent, benevolent, and all powerful despot who should have absolute control of all real estate in the city. Such a monarch could take all the railroad holdings, shake them up together, and issue them out again to the different roads. as in his wisdom seemed best. But if he were to undertake to make a complete and satisfactory job of railroad relocation, his jurisdiction would have to be extended over a considerable portion of northwestern Indiana.

But the situation is not so hopeless; railroad managers realize that straggling individual action will not accomplish the result desired, and some day there will be an intelligent concert of action that will give to this city what it so much needs, abolishment of grade crossings. Let the people meet them half way, not forgetting for a moment that the railroads and the Lake have made Chicago, and that her prosperity, both depends upon and promotes, the continuance and the growth of both Lake and Rail commerce.

COL. ROSWELL B. MASON

First President of the Western Society of Engineers.

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ROSWELL B. MASON.—A MEMOIR.

BY WM. SOOY SMITH, Chairman, DEWITT C. CREGIER, A. GOTTLIEB, BENEZETTE WILLIAMS, AUGUSTINE W. WRIGHT, E. L. CORTHELL, SAMUEL G. ARTINGSTALL, WILLARD S. POPE, CHARLES PAINE, COMMITTEE OF WESTERN SOCIETY OF ENGINEERS.

Roswell B. Mason was born in the town of New Hartford, Oneida County, New York, Sept. 19, 1805, died Jan. 1, 1892, aged 86 years 3 months and 13 days. His earliest ancestor in this country was one of Oliver Cromwell's dragoons, a member of the famous "Ironsides" troop of horse, who emigrated to Massachusetts about 1649. His grandfather was a soldier of the revolution, who fought for freedom at Bunker Hill, Bennington and Saratoga. His father was a captain in a New York regiment, in the war of 1812, and was by occupation a farmer, merchant and contractor upon public works, one of his principal undertakings having been the building of the High Bridge over Harlem River for the Croton Aqueduct to New York City. The son in boyhood attended a common district school, principally in the winter, and worked on his father's farm during the school vacations. He also had two years schooling at an academy in New Hartford.

In 1821 his father had a contract for delivering stone at some of the locks on the Erie Canal near Albany, and for two seasons he was employed in this work under his father. In the spring of 1822, the son went into the engineering department on the Erie Canal and continued in that employment until 1824, but found time during the two winters to attend a select school at Utica, N. Y., and gave attention particularly to engineering studies. In the spring of 1824 he was employed

on the Schuylkill Canal, in Pennsylvania. He was next engaged in running a survey for a canal from Lake Champlain to the St. Lawrence River, and in making maps and estimates of the contemplated canal, but the great elevation and expense of the route prevented its being built. The present railroad from Lake Champlain to Ogdensburg passes over much of the ground which he surveyed for a canal. From 1825 to 1831 he was employed successively on the Morris Canal in New Jersey, the Delaware and Raritan Canal and the Mauch Chunk Canal in Pennsylvania, returning to the Morris Canal to take the position of principal assistant engineer. In 1831 he took the same position on the Pennsylvania Canal, having charge of its northern half.

On Sept. 6, 1831, he married Harriet Lavinia Hopkins, and their wedded life continued until her death on March 29, 1891. The Pennsylvania Canal was completed in 1832, and in the following year he was employed as superintendent of one of the branch canals of the Morris Canal Co., and then in the same capacity on the Mauch Chunk Canal, where he remained until the spring of 1837. In that year he had charge of the construction of a feeder up the Pompton River and a large reservoir at Long Pond, one of the sources of the river.

The age of railways was now about beginning and the curiosity and attention of men, in general, and of engineers, particularly, were powerfully aroused by the new method of transportation. During the winter of 1836 and 1837, Mr. Mason made a survey for the Housatonic Railroad in Connecticut, and became chief engineer of the road, but for a time continued also in charge of the feeder and reservoir in New Jersey, which were finished in the fall of 1837. The construction of the Housatonic Railroad soon engrossed his whole attention, however, and in the spring of 1838 he moved his family to Bridgeport, Conn. He remained with the Housatonic Railroad as engineer and superintendent until 1848.

A characteristic anecdote of Mr. Mason's care and firmness as a railroad manager has been preserved. One train had been directed to wait on a certain sidetrack until another train had passed safely by. "How long must I wait?" said the impatient conductor. "Wait till your wheels rust off," was the memorable reply. Had this spirit prevailed generally in railroad management, the records of accidents and collisions would have been materially lessened.

In the spring of 1848 Mr. Mason was appointed chief engineer of the New York and New Haven Railroad, and remained on that road as engineer and superintendent until the spring of 1851. Upon retiring from that road, he was presented with a massive service of silver, an elegant tribute of affection and respect, but he has since declined similar testimonials from a feeling that poor men might be called upon to contribute when they could not afford it.

In the spring of 1851 he was appointed chief engineer of the Illinois Central Railroad in Illinois. He organized several engineering parties and commenced the survey of the road about the first of June, beginning surveys simultaneously from Chicago, Urbana, Jonesboro, Vandalia, Bloomington, LaSalle and Freeport, and locating the entire road, seven hundred miles, in the fall of that year The construction of the road depended upon the land grant of about 2,600,000 acres, which had been donated by Congress in alternate sections for building the road. The winter of 1851 and 1852 he spent mostly in Washington City to get the United States Commissioner of the Land Department to designate the lands. He returned to Illinois early in the spring of 1852 and began at once the actual construction of the railroad. The first contract was let in March, 1852, and the entire seven hundred miles of road were completed or the last rail laid, in October, 1856. In 1855 he examined the route for a ship canal between Georgian Bay and Toronto, associated with Mr. Shivas Sibley, of this city. For the next four years he was engaged mostly in railroad construction in Iowa. In 1860 and 1861 he was superintendent of the Chicago, Alton and St. Louis Railroad, and during a part of the time was receiver of the Logansport and Peoria Railroad. During the next six years he was comptroller of the land department of the Illinois Central Railroad. From 1865 to 1869 he was a member of the Board of Public Works for lowering the summit of the Illinois and Michigan Canal for sanitary purposes. In August, 1867, he was appointed chief engineer of the Dunleith and Dubuque bridge, which was finished in December, 1868.

Nov. 2, 1869, he was elected mayor of the city of Chicago and continued for two years until December, 1871. The great fire in Chicago occurred Oct. 9, 1871. A conspicuous instance of courage and duty in his administration is the fact that he refused to allow a clamorous faction of the Common Council to dispense the charitable donations which poured into the city, but turned the funds over to an established organization—the Relief and Aid Society. Only a person, who has been in active politics, can understand the pressure, which he withstood. Had the world's charity been diverted in any way from its legitimate purpose, it would have been an eternal disgrace to the city.

He had retired from actual business shortly before the fire, but retained his faculties and interest in public affairs until the last. After the age of seventy years he made a trip to Europe and another to California with his wife, and they built a new home for themselves in Chicago, which they lived to enjoy many years. On Sept. 6, 1881, the fiftieth anniversary of their marriage was celebrated in the presence of children and grandchildren. Mr. Mason took much interest in the present drainage canal project, and took pleasure in discussing it with

the younger generation of engineers, which had grown up about him. Shortly before his death he contributed to the daily papers a very clear and well-considered article on the advantage of passing the required volume of water through a broad and shallow channel, which would be mostly earth excavation and, therefore, comparatively inexpensive, instead of a deep and narrow channel, which would require costly rock cutting and blasting. Mr. Mason had been an elder in the Fourth Presbyterian Church for many years, and a trustee of the McCormick Theological Seminary.

Seven children survive him—Mrs. Henry G. Miller, Mrs. James H. Trowbridge, Edward G. Mason, Roswell H. Mason, Mrs. W. F. G. Anderson, Henry B. Mason and Alfred Bishop Mason. He leaves an estate of $700 000, equally divided among them.

The many who knew Col. Mason during his long and useful life, knew him to be a great engineer, a prominent and influential citizen, and a quiet, christian gentleman.

His uniformly successful professional services furnish abundant evidence of the soundness and strength of his judgment, schooled, as it was, by large and varied experience.

He was the oldest member of our Western Society of Engineers and its first president.

He was uniformly and persistently industrious, energetic, efficient and successful, deserving and receiving the unbounded respect of his associates in business, professional and social life.

And so through his long and great career he was beloved by his family and friends, admired by his co-workers, and trusted and honored by the communities in which he lived.

The Western Society of Engineers has had no member more highly esteemed than Col. Mason; none whose death has been more sincerely lamented, and none whose memory will be longer or more tenderly cherished.

THE RELATION OF THE ENGINEER TO THOSE WITH WHOM HE COMES IN PROFESSIONAL CONTACT.

A SERIES OF PAPERS READ BEFORE THE BOSTON SOCIETY OF CIVIL ENGINEERS, MARCH, 15, 1893.

The Relation of the Engineer to his Brother Engineer.

BY DESMOND FITZGERALD, C. E.

At the last annual meeting of the American Society of Civil Engineers, the writer had the pleasure of assisting in the passage of a resolution asking the Board of Directors to inquire into the advisability of adopting a Code of Ethics and to report thereon.

The importance of this question becomes more apparent the longer and the more faithfully we study the present condition of the profession of the Civil Engineer in this country and the relations of the engineer to his brother engineer. To those who are contented with the present status any appeal looking towards improvement will be made in vain, but happily there are many who are animated with the laudable ambition of seeing their profession take the same rank that it does in those countries where it is looked upon as the very foremost among the learned professions.

It appears at first glance that no other code or rule of action can be necessary than that common rule which should be observed by all men in their relations to each other, known as the golden rule, "Whatever ye would that men should do to you, do ye even so to them."

This is of course all comprehensive. Unfortunately it has been found by experience that in the complicated relations of modern civilization, with the mad strife for position, honors and pecuniary rewards, —certain laws, constitutions, rules and regulations, specific in character, are necessary to form bonds of union and standards of conduct. One of the advantages of having some code is that when framed by the deliberate and well considered thought of men of wisdom and experience it necessarily has an influence on actions which, without it, might, in the haste of the passing moment, and without due consideration, prove injurious to our fellow man and unworthy a high standard of professional honor.

Disagreeable as it may appear to contemplate, we must nevertheless acknowledge the truth of the assertion, so often made, that in this country the professions of law, medicine and theology far outrank that of the engineer in the public mind. May it not be that one of the rea-

sons for this difference arises from the fact that these professions have certain defined rules of conduct, or codes of ethics, which tend to give them a high place in the esteem of the community.

Let us look for a moment at the profession of medicine. The writer has abstracted from the Code of Ethics which serves as a guide to the Massachusetts Medical Society the following articles bearing upon the relations of the physician to his brother professional.

Massachusetts Medical Society, Code of Ethics.

IV. The relation of the Physician to other practitioners and to their patients.

In his relations with another medical practitioner and his patients, a physician should be governed by strict rules of honor and courtesy.

His conduct should be such as, if universally imitated, would insure the mutual confidence of all medical practitioners.

The foregoing rule should be a sufficient guide of action.

Some of the following contingencies will illustrate its application.

1. A physician should take no step with a view directly or indirectly to direct to himself the patient or practice of another physician.

2. If formally requested to assume charge of a patient or family usually attended by another physician, he should consent to do so only after notifying the latter—unless the case be one of pressing necessity.

3. If a physician is called to a patient during the temporary absence or illness of the usual physician or in case of accident or other emergency, he should direct that the former be sent for as soon as he is able to take charge of the case, and should then relinquish it to him. It is generally agreed that, among several physicians thus called, he who first arrives shall act, unless the family designate another.

4. A communication from the temporary to the usual physician, in the absence of the latter, should be written and sealed, and not simply verbal.

VI. Consultations. Consultations should be encouraged in cases of unusual responsibility or doubt.

A consultation is called for the benefit of the patient, and to give him the advantage of collective skill. Should there be a difference of opinion, discussion should be temperate, and always confidential.

A consulting physician should be careful to say or do nothing to impair the confidence of the patient or his family in the attending physician.

Does anyone doubt that the observance of these rules tends to elevate the profession of Medicine? It seems to the writer perfectly plain that a body of men who thus have the wisdom to respect themselves, must win the respect of others. The honors and emoluments which, as is well known, attend the diligent practice of Medicine, follow as a matter of course.

Some men of high rank in engineering go so far as to proclaim openly that there is no such thing as a profession of engineering, and

that while men continue to work for a salary, there never can be one. This was asserted at the annual meeting already referred to. We may well wonder why there should be one rule in this respect applicable to the clergy and another to the engineer.

If we throw overboard all pretensions to a profession, what have we left? Shall we degrade our science to the level of a trade?

Let us glance for a moment at some of the more glaring evils that now surround the ordinary practice of the engineer so far as his relation to his brother is concerned.

First in importance may be placed the strife to secure work that properly belongs to another.

Secondly, jealousy of the success of others.

Thirdly, ungentlemanly treatment of subordinates.

It is hardly necessasy to cite cases where engineers high in the ranks openly solicit employment, or by some indirect method endeavor to capture work which would naturally go to another. Probably every engineer will recall plenty of examples from his own experience. Such conduct is hardly compatible with that high sense of honor which ought to animate every professional man. Not only is the respect of the community lost by these means, but the ultimate rewards which every one should attempt to raise in a proper manner, must be very much lowered.

It is undoubtedly true that many men should have the credit of transgressing in this regard through actual ignorance rather than from a desire to secure work at the expense of others and of the profession. It is easy in the absence of formulated rules of guidance, to fall into the methods of the travelling salesman or the subscription canvasser. The result is often that the public get their engineering advice for next to nothing, and sometimes their plans for one-half the cost of a proper preparation. The writer believes that prices would naturally rise to a point nearer their proper level and all members of the profession would be much benefited if the lines were drawn a little tighter around the relations of the engineer to his professional brother.

In regard to jealousies which arise in the profession, the writer can only say that criticisms of one engineer by another, are in his judgment, far too common. Unless improper methods are used in the conduct of business, every engineer should be careful to abstain from adverse remarks in regard to his brother, because such remarks may possibly injure him in his business. It has not infrequently happened that the most malicious stories have been started by some one calling himself a civil engineer, prompted by jealousy of the success of another. We should really remember in this connection that the higher any rival climbs in the esteem of the public, the greater become the chances for us to attain the same success.

The writer was once thrown in his earlier professional life under the charge of an engineer whose great delight consisted in hurling volleys of oaths at his assistants and treating them like a lot of inferior beings. Happily this type is fast passing away. Such conduct neither produces the most work, nor accomplishes the best results. It was, however, a type often met with in the earlier days of engineering, and generally found hand in hand with ignorance and rule of thumb methods. Can we wonder that with such examples before them, men have grown to mistake cheek for business aptitude. In this connection the following story may not be altogether out of place:

An eminent landscape gardener not long ago had occasion to employ a young engineer to assist in the laying out of a certain work, and in order to familiarize him with stock phrases used by this branch of the profession took him for one day to a public park and pointed out certain features in order that he might understand the meaning attached to his instructions. On the strength of this one day's apprentice-ship, in an art that was new to him, the young man soon afterwards added to his title that of landscape architect; and furthermore had the audacity to send the advertisement to his employer. In this advertisement he described himself as having been the pupil of this eminent and experienced practitioner. The man was, of course, nothing more nor less than a quack. He had never learned his profession, and was simply trying to take a short cut for practice in a profession requiring years of preparation and hard study.

A fitness to fill the duties of a civil engineer does not by any means depend upon a college education. That such preparation aids materially in success, none will deny; but we cannot lose sight of the fact that many of the brightest lights in the profession have been men who, after a proper period spent as pupils or assistants, have by continuous study all their lives, achieved the highest results. It is needless to say that such men are not found guilty of the petty meanness of pulling others down, while mounting the ladder themselves.

Whether it is best for American Engineers to be guided by some written code of ethics, the united wisdom of the profession will undoubtedly determine. If proper rules should be adopted, it is evident that aside from their usefulness to the profession, they will be a desirable aid to the public in their dealings with the Civil Engineer.

The Relation of the Engineer to the Public.

By John W. Ellis, C. E.

The relation of the Engineer to the public, both as its servant and as an officer, seems to me is the short and long of the topic for discussion this evening.

It is a subject of such broad scope, and of such interest and importance to every member of this society, that it seems to me it would be impossible, for an engineer to remain silent, if he fully considers his duty to himself and to the public, and for that reason I am here this evening.

The engineer, through his education and his calling, or rather I prefer, his profession, is brought in contact with business men and public officers of all kinds and stations. It is from the labor and estimates of the engineer, from his recommendations as to the feasibility and practibility of the enterprise that the foundation for the most important public improvements is based, and I might truthfully add, that the officer to whom he reports, really uses the information given to him by the engineer as the real substance of his reports, and very often receives the credit and praise as having not only been the originator and promoter of the enterprise, but also the manner in which the work should be done.

I believe that the engineer should assert himself, and that, through the influence of a society like ours, he himself should be able to show the public that he was equally as able to manage and dictate public improvements as he is to make plans and estimates for their conception: that he should identify himself with public matters, becoming a public officer, and in that way coming in contact with public men of all professions and of all kinds of business. In this way, he not only will promote public interests and his individual welfare, but also, if he be true to the profession, will aid his associates and increase the influence and standing of this society.

The legal profession make themselves not only known but felt at every opportunity, in fact, they believe that their success individually and as a fraternity depends entirely upon their contact with the public, and as public officers. I believe the engineer is well fitted to become a public officer, to be a trustee, a receiver or director of corporations, municipal or otherwise, to serve as commissioner, councilman, alderman, mayor etc., in fact, much better than those his inferior in education and experience.

In regard to political association, I think it [is his duty to associate himself with the party which he believes to be the best for the promo-

tion of the public interests, and to make himself prominent in that party; to become acquainted in that way with public matters and whenever there is the necessity for any public improvement, requiring a commission to be appointed, to insist that his profession should have a representation.

In this connection I refer to an instance in your own State when an act for the establishment of a Board of Railroad Commissioners was established by the Legislature of Massachusetts, it was understood that it should be composed of a lawyer, a business man and an engineer, but it was not made a part of the act as it should have been and I maintain, that if engineers had been members of or appeared before a committee of the legislature, they would have insisted that this should be incorporated in the act. The intention of the act, however, was carried out in the first appointments and continued to be so until one of your Governors in making the appointment, decided to dispose of the services of the civil engineer on that commission and fill his place by a member of the locomotive engineers, (and I say this with no discourtesy) and since that time there has not been an engineer as a member of the Board of Railroad Commissioners. If the lawyer had been disposed of instead of the engineer, do you think the legal fraternity would have been satisfied to remain silent. It was also intended that when the act for the abolition of grade crossings in your state was established, that the commission would be composed in a similar manner, but this rule is not followed, as last week a judge in the appointment of a commission for the abolition of these grade crossings in the City of Worcester, appointed three lawyers on this commission. If he had appointed three engineers, it would have been much more suitable, for this work is almost wholly of an engineering nature.

How and in what manner can engineers make themselves prominent in public matters?

It seems to me there are many ways of doing this.

This society could appoint a committee, whose duty it should be to report what acts are being passed and what new acts are necessary for public convenience and business, for engineers should be originators of methods, and this committee should attend the hearings and show by their presence that engineers are interested in public matters, and demand public recognition, or, our President could be made a committee to attend to these matters, and I believe should be paid for services rendered in this capacity.

Every one knows that a successful business man is the one who is constantly on the alert, identified with the business interests in the community in which he lives, and in this way his business is increased, his advice is sought after and respected; so also should it be with the engineer, he should not be satisfied to go to his office in the morning

and leave it at night and continue this routine of duty day after day, month after month, and year after year, but he should devote some of his time to public matters, interest himself in all public improvements, and demand that he shall not be at the beck and call of other officers, but a man among men, and the peer of the majority of men.

Let us hope that in the year 1893 which promises so much of interest to the members of this society, not only at our World's Fair, but here in New England, that a new departure will be inaugurated,—certainly, let it be known in the cities and State-houses of New England that the Boston Society of Civil Engineers is in existence and not only is willing, but proposes to help solve the problems of Rapid Transit, better Roads, of improved Terminals, of elimination of Grade Crossings, of improved Sewerage etc., in fact Mr. President, let its influence and advice be required in all public matters and public improvements.

The Relation of the Engineer to the Public and to the Press.

By Wm. E. McClintock, C. E.

The good book tells us that the same people who spread palm leaves one day, cried crucify him only a few days later.

Many an engineer who has held positions of public trust has gone through a like experience. However good they may be or however perfect their work there is sure to come a time when it is all forgotten and he is removed from office under a cloud, the opposition coming from a few dissatisfied persons, while the great public look calmy on wondering how it is possible for such a good man to go wrong.

As engineers we expect to be criticised by the public, as they decide as to the value of works, solely on the ground of personal benefit. When the engineer is at work on his own business he is a specialist and not one of the people. He must range far ahead of them and be a leader of public opinion. To do this he must be posted on every part of his subject and educate the public up to his standpoint by talking in season and out of season. The educational part should come before the subject comes up for final settlement and then the governing body can vote understandingly on it.

One of the great cries of the day is that raised by the public against the corporations. They are spoken of as the greatest enemy of the public and any scheme which they propose is taken as another attack on the people, an effort to take away the few remaining rights they may have. The engineer should never join in such attacks. He should be the judge rather than the critic. Because the party urging the

improvement is a large corporation it does not follow that their only object is to take the peoples rights. Any great public benefit must work injury to a part of the people and they perhaps feel that great injury is done them but the great majority receive a benefit.

In the investigation of the state highways just made by the commission, it was found that between three and four millions a year are expended on highway improvements. In but very few instances are records kept which show where this money is used or how. We see such items in the annual report as this, viz. "Pay roll $2,000, or $6,000. John Jones, supplies: $1,000." In but few places is any attempt made to obtain an itemized account of the expenditures and the heads of departments can give no information. I say it is the duty of the engineer to educate the people up to a point where these records shall be kept, in spite of those who disapprove. The people should know where this large amount of money is going to and by knowing what a work costs judgment may be passed upon it as to whether it costs too much. My attention was brought to this subject to-day when looking over the works of The Geo. F. Blake Mfg. Co., at Cambridge. After we had gone the rounds of the works and returned to the office we were shown the little slips of paper and time clocks on which the mechanics time was recorded so as to make a record of just how many hours he worked on any one part of any work he was engaged in. A record of this kind makes it possible to know whether money be made or lost on the work without waiting till bankruptcy convinces one that no money is being made. My own experience in this line is a good example. When I took charge of the streets of Chelsea there was no record kept and in my simplicity I attempted to make one. I was told that it was all nonsense, that we had so much money to use and when it was gone we would have to stop. One of the first things I discovered was that it was costing us $1.75 a ton to break stone. On inquiry in other towns I found this was too much money. On examination of the methods I found an antiquated system which required a large force of men. This was remodeled and the cost of breaking was reduced about 50 cents per ton. This is but one of many illustrations which could be given.

Every time a lawyer does anything it is carefully noted in the papers. I have been repeatedly told during the past year that the Boston Society of Engineers worked so quietly that no one knew of its existence. We come here night after night and talk over business which largely interests the public and in our modest simple way we keep it to ourselves. I see no reason why the Boston Society should not be ready and willing at all times to place itself on record either for or against any important public improvement. I do not mean to pass a snap judgement but to appoint a competent committee and act on their report, and then boldly work for it.

The Engineer in his Relations to his Clients.

By Augustus W. Locke, C. E.

On looking into this subject, the question is whether the relations existing between the engineer and his clients are what they ought to be, and what changes if any are desirable.

Here we find a large body of educated men: all of them have given years of time and study and effort to qualify themselves to do their work. They are faithful to their trusts. Who ever heard of an engineer accepting a bribe? They are almost never accused of enriching themselves at the public expense. Indeed they seldom enrich themselves at all. After controlling the disbursement of millions, they generally go to their long homes leaving little behind them except untarnished names. It is not for lack of opportunity, and the temptations are not wanting; but the class of men who adhere to the engineering profession are of those who expect to work and render an equivalent for what they get rather than to succeed by gaining an advantage over others by deception.

The results of the engineer's labors are expected by his clients to be absolutely accurate. His work has got to turn out as he says it will turn out, or else he runs the risk of losing his reputation. He expected to do accurate work and furnish accurate opinions, and he does it even though it be a new and unknown matter. Where else are there any such requirements or any such results? I do not know where to look for a parallel. Brilliant as have been the effort of men in other professions, yet we may see that about the whole earth is strewn with the disastrous results of their mistakes.

The engineer has a very high reputation for fairness, and a capacity to render wise and just decisions. The contractor voluntarily puts all his interests into his hands although he is in the employ and pay of the other party in the controversy and the points of dispute are in the beginning entirely unknown.

Such is the engineer's character, and such the service rendered by him to his clients and to the world at large; but I venture to say that his position in the world's procession is not what it ought to be, and he does not in my opinion receive his just share of the wealth which his labor creates. The boasted progress and material advancement of the present age are to a great extent dependent upon him; without him many things would come to a stop. Take away the results of his labors and what have you left? But for all that nobody hunts him out to confer political honors on him, not even when questions which he only can decide are involved do we find state or national governments

by any means in a hurry to seek him out and place him in charge of the question. He often gets left out when matters in his own field are being decided, and as for calling upon him to decide any case outside of his own sphere, probably it is seldom heard of.

Commsssions for deciding and administering engineering questions are often made up without him, and he is called in to perform the humble duty of doing their work for them.

Where he holds official position, the tendency is too much to curtail his authority, so that he too seldom stands as the executive head of a department responsible only for results and having control of all labor and material. There is where he should stand always. He is trained to know the reason of things, and to do all work the most economical way, and to use labor to the best advantage; and he can do all these better than any body else if he is what he ought to be. And furthermore he is certain to be a stumbling block in the way of the official boodler.

As to pay, there has certainly been a great improvement since the middle of the last century when the great Brindley was building English canals at three shillings a day; but I venture the opinion that the financial return which the engineer receives is not what it ought to be considering the severe and exacting nature of his duties and their great importance in the creation of the world's wealth. If any are disposed to dispute this view, I would ask that they look about them and observe the plain manner of living, the lack of luxury and display and the small evidences of wealth exhibited by nearly all engineers, even including those who have the best positions and the most lucrative practice.

These disadvantages which we labor under I regard as being due to the fact that the engineers are very modest in their requirements, and furthermore that they have never heeded the principle that in union there is strength.

If they want things, they must demand them and take means to enforce their demands. They should act together for their own common good. The engineering society should not be for the sole purpose of exchanging experiences, but rather to strengthen the position of its members and to uphold their dignity and to influence public opinion for their benefit. On all public questions affecting the interests of engineers, the society should act as a unit and make itself heard and felt. The requirements for full entrance should be severe and high, and the society should establish for its members their minimum fees, and regulate so far as practicable their relations to each other and to their clients. It should throw over them a mantle of protection, and discourage the process by which the client is enabled to crowd down the fees by inducing engineers to bid against each other on the same work.

By the enforcement of some such improvements as are above set forth in the relations of the engineer to his client, both parties would be benefitted and also the whole community would reap the advantage of better work and in many cases, a more economical use of money.

Relation of the Engineer to his Assistants or Subordinates.

By Albert F. Noyes, C. E.

An Assistant or Subordinate is a person who may be assisting or be working under the direction of another. So that the consideration of this subject is applicable to all from the lowest to the highest in authority.

The assistant or subordinate may be so, as a result of circumstances, or from a lack of opportunity to fill the position for which he may be fully able, from his experience, training and education to fill with credit, or he may be just beginning his professional career, fresh from school or college with more or less technical training and little or no experience practically in the work of the profession or calling (by which ever name it may finally be called.) In either case it is the duty of the engineer and each assistant, to his clients and himself, to not only avail himself of the best efforts or services of the men who may be assigned to assist him, but to do all he can to increase their efficiency and ability to assist.

I hazard the prediction that none of us were made perfect in our beginning, and but few have reached perfection at the present time, so that the battle for a better condition of things is constantly being waged and there are none of us but are dependent upon the other for assistance, advice, or support, and in dealing with each other we should, before acting, ever ask ourselves the question, "how would we have them deal towards us were the conditions changed" and act upon the answer we can give ourselves.

As illustrative of how small an incident may influence or determine between success and failure, I recall a kindly act of a school-mate, to which I attribute much of what little success I may have attained in life.

During my freshman year at the Lawrence Scientific School, I struggled in vain for months to master a portion of the mathematical course. An acquaintance belonging to the senior class seeing my trouble and its probable cause, gave me his assistance for about two weeks, during which time I was taught how to reason as I never knew before.

Later in life the lesson of helpfulness has been repeatedly taught me by the actions, words, and simplicity of manners of such eminent Engineers as the late James B. Francis, E. S. Chesbrough, Moses Lane, orof our contemporaries William E. Worthen, Phinehas Ball, Joseph P. Davis, A. Fteley, Rudolph Hering, and many others who have attained high positions in the profession. What engineer who has had the pleasure of a personal acquaintance with any of these gentlemen but what can recall the kindly greeting and expression of personal interest he has received. Who has ever applied to them professionally for advice or for a statement of the results of their experience upon any problem which they have had to solve, but have found them ever ready to forego personal pleasure or ease, to assist. I do not believe the man can be found.

I well recall the expression used and injunction made to me by one of these gentlemen who had incurred considerable personal expense, and who had given me a considerable portion of his time for a day without expectation of compensation in order that I might fully understand the methods used, and the results obtained from original work which he had successfully executed and which might assist me in more intelligently executing certain work which I was planning: I refer to it here in hopes it may impress others as it did me. Upon protesting against his putting himself out to the extent he must have, for he was a busy man, he replied, "I am an older man than you, and this gives me a right to do as I please. What we older engineers know we have learned by hard and busy years of work and study. Now it is not right that we should carry our knowledge to the grave with us, without doing what we can to impart it to others. All I ask of you is that as you grow older and take our place in the profession, you will do what you can to assist the younger engineers with whom you may come in contact."

In order to get the best results from the services of an assistant or subordinate, he should be brought in as close contact as possible with the mind of the engineer. He should be early taught to reason and to constantly put forth his best efforts. No mind however mature, can grasp at once all of the conditions affecting the most perfect solution of engineering problems. I have often found that the most satisfactory results have been obtained by having consultations from time to time with the assistants who may have connection with the work in hand. To invite a free expression of opinion from them and if found desirable to adopt other methods than those proposed by them, to clearly state the reason therefore.

By this means all minds are kept in close touch with each other and better results obtained in the execution of any work.

Finally each subordinate should be given full credit for the suc-

cessful execution of any work of which he may have charge.

In my practice when any new problem is to be considered, the assistants who are likely to be ultimately connected with its design or execution are advised of the fact, the details of what it is desired to accomplish, and all information which would be likely to affect its proper solution so far as known, is laid before them. They are asked to keep the subject in mind. At the proper time we jointly consider the details and perfect our plans. In other words, we all work together to accomplish the best results. By this means united action and loyalty of service is obtained.

The Engineer as an Expert Witness.

By M. M. Tidd, C. E.

One of the most delicate and to my mind disagreeable duties that an engineer is called upon to perform is that of an expert witness. He is employed by one side of the case, and is expected to testify in such a manner as to give the greatest benefit to the case of his client, while the experts on the other side are expected to do the same for their side of the case. Thus we have the spectacle of two sets of engineers of equal standing and ability testifying in the same case, each endeavoring to controvert the testimony of the other. Should either not succeed in doing so his client complains, and in many cases objects to the bill.

The natural result of such a condition is to bring the profession into disrepute.

Some of the testimony in cases that have come under my observation has been enough to bring contempt upon even a lawyer's profession.

I have in mind a case which may serve as an illustration. It was a case where a suit was brought by the owners of a mill against a town which had supplied itself with water taken from one of the sources of the stream from which the mill obtained its power, or at least a portion of it. As the water power was unreliable the mill was supplied with steam power enough to run it entirely, and at the time of the trial of the case it was doing so.

It was proposed by the defendant to make restitution by a sum of money which would replace by steam the power lost by the diversion of the water.

The plaintiff claimed that a complete plant to furnish that amount (about 7 horse power,) an engine, boiler, power-house and the salary of a man to run it, should be paid for. The defendant demurred and claim-

ed that it should simply pay for the coal used in the present plant to give the 7 horse power required. The plaintiff on oath declared that his engine was taxed to its utmost capacity to run the mill, and that it was impossible to get another horse power out of it.

At this point the court adjourned for two days, and the experts for the defendant never having seen a mill run up to its utmost limit, having the curiosity to see it, visited the mill the next day. There was one main shaft running the entire length of the building, at one end of which was permanently connected three 30 horse power turbine wheels, standing in about 8 feet of dead water, while at the other was connected a steam engine running very finely, driving the entire mill and the three turbines. This was certainly a rich find for the experts. Upon interviewing the engineer the following dialogue took place:

You have a good engine there. "Yes, first-class."

Runs the mill very easily.

Oh! yes.

How much more power could you get out of it if necessary?

Oh, well, 10 to 15 horse power.

Do you always carry the three water wheels when you run the mill?

Yes, there is no means or disconnecting them.

How much power do you suppose you are wasting on them?

Well, probably 50 or 60 horse power.

Now this was the steam plant which the plaintiff testified could not turn out another horse power.

It is needless to say that this engineer was invited to testify at the next session of the court, which he did honestly.

I merely quote this as one instance of the many that have come under my observation where such reckless testimony is indulged in. Such testimony is certainly no credit to our profession.

There is another disagreeable point in this portion of an engineer's profession in that he is often called upon to testify before a stupid jury or a commission, members of which are equally stupid.

I remember testifying in a case before a commission of three lawyers. The hearing was continued for 22 days. There were seven engineers in the case and each one was required to give a statement of what constituted a nominal horse power, which each one did very clearly and carefully, all agreeing in every detail.

You can perhaps imagine our disgust when on the opening of the 22nd day's session one of the commissioners stated that he had used his best ability during the hearing to comprehend the merits of the case but so far he was totally unable to understand what a horse power was ! ! !

Such case as this can hardly give an engineer much respect for commissioners, or satisfaction in testifying before them.

It seems to me that an engineer should have a clear understanding with his client as to the merits of the case, and as to what he expected to testify to, before he agrees to enter the case. He should not regard a case entirely from the standpoint of how much money he is to get out of it. He cannot afford to sell his reputation at any price.

I remember a case where I was asked to testify, but upon investigating it I was satisfied that the party had no case, and distinctly so informed the counsel, who replied that that was his business and he could not understand why I would not enter the case if he was willing to pay me for it. I could only reply that I could not take his client's money unless I could render him a service equivalent to it. In this case my answer to the first question would be fatal to his case, therefore I could not testify for any price.

There is another difficulty in this portion of an engineer's business that is exceeding disagreeable, which is the uncertainty as to when he will be called upon to testify.

He gets his figures all ready and after much study gets the case clearly in his head and is notified that he will be called upon the stand to-morrow morning; he makes all his arrangements accordingly. When he appears at the hearing he is informed that the case is postponed for a month. When that time arrives he has forgotten his testimony and must read up anew.

I think the whole manner of doing that business is wrong. The experts should be called by the court, and the expense assessed as in the case of any other "costs."

In that case the expert would feel under no obligation to either party and would have no client but the court.

The Influences of his Profession upon the Social Relations of the Engineer.

By Henry Manley, C. E.

I will say a word or two concerning the nature of the work of the engineer in comparison with that of the three so-called learned professions. The Law, the Ministry and Medicine.

The work of the Lawyer concerns questions which grow out of the relations between man and his fellow-man; the Minister deals with questions which arise between man and God; and the Doctor with the relations of man to his own mechanical system. I claim that the Engi-

neer is a man who administers the laws of physical nature for the benefit of mankind.

The profession of medicine most nearly resembles that of the engineer, for so far as the doctor investigates and applies natural, physical laws to the benefit of his patients, in so far he is working in line with the engineer, and in modern civilization the engineer is constantly involved in questions concerning the public health. But the doctor has to deal with the peculiarities of individual humanity, and his profession, while emerging from countless years of darkness and groping, is still so obscure as to leave wide open the doors of success to incompetence and quackery.

The law which the clergyman expounds is not codified to the acceptance of all mankind, and from its nature is hardly susceptible of entirely clear definition, and a large part of his energy is expended in attempts to prove that the particular code which he administers is the true and only one.

The lawyer deals with statutes, ordinances, constitutions and precedents, which change from day to day, and which are susceptible of the most various constructions.

The engineer deals with the laws of God as shown in the physical universe. Of these laws, mankind has learned a few, and only a few of the simpler ones. The engineer is certain that a natural law once known is always known, that he can depend upon it under all circumstances, that it is never repealed or suspended, and that a violation of it, whether willfully or ignorantly made, is instantly and inevitably followed by the proper penalty. As a natural consequence he has a most profound respect for it.

While human law is proverbially uncertain, the practice of medicine so filled with uncertainty as to be the prey of hordes of quacks and "Patent Medicine" cranks, and the subject matter of which the minister discourses admits of the wider differences of opinion and practice, the simple laws of nature which the engineer administers are universally accepted and respected, and are neither doubted nor scoffed at.

In the light of the laws constantly before him, the engineer is first of all an honest man. Dishonest men may perhaps succeed in other professions, but I do not see how an engineer who is not honest and trustworthy, can be successful.

If the status of the engineer as a professional man is judged by the mental labor required to fit him for his duties, he may safely challenge comparison with either of the learned professions. Casting aside the general intellectual training considered almost or quite essential for the Lawyer, Doctor and Minister, and which is equally desirable and essential for the Engineer, I contend that the mental effort re-

quired to master the existing knowledge of the world in engineering, is much greater than that required for equal attainment in either of the above named professions.

The engineer, in common with the rest of mankind is desirous of eminence amongst his fellows. The first position in the eyes of the world belongs to the successful soldier. No other fame may equal his. It is not given to all of us to become famous engineers, but there is no position in life known to me that presents more opportunities for helpful work for his fellows and for mankind in general than that of the engineer, and as I call to mind the most distinguished engineers that it has been my fortune to know, the first thought is not of their eminence as engineers, but of their honesty of mind, and their wise and kindly helping ways. Particularly is this true of our lately deceased fellow member and past President. When we think of him it is not as the famous engineer,—all the world knows him as that,—we know and remember the kindly, helpful, lovable friend.

As I have said before, it is not given to all of us to be great engineers. It is given to us to be honest, straight forward, helpful men, and to deserve the respect and affection of our brother engineers, and that kind of fame we may all strive for and obtain.

MECHANICAL ENGINEERING.

Report of Progress in the Past Year, By W. R. Warner, Member of The Civil Engineer's Club of Cleveland.

[Read March 14, 1893.]

The work of the Mechanical Engineer during the past year, as indicated by the transactions of the American Society of Mechanical Engineers and in current engineering periodicals, as well as by observations all along the lines, has been largely centered in the improvements in methods and systems of transportation and of manufacturing. Processes of former years, which were thought to represent the best solutions of the old problems, have been so improved as to be hardly recognizable, and while so much still remains to be accomplished, we shall look to the science of Mechanical Engineering and its many branches for still greater progress in the future.

The Mechanical Engineer has made notable advances in railroad equipment, and as a result his latest improved locomotives and rolling stock are designed and constructed on such accurate principles that but an eighth of a cubic inch of coal, like this piece held in my hand, is required to transport a ton of freight one mile.

Even better economy is assured by the introduction of the Compound Locomotive now being thoroughly tested, while the results of the Compound Marine Engines of the triple and quadruple expansion types have surpassed even the most enthusiastic hopes of their advocates.

Our lake transportation presents a remarkable example of the recent great progress of mechanical engineering. By the courtesy of Chief Engineer C. B. Calder, of the Mutual and Menominee Transportation Companies, I was given access to the record of their new ships, which are propelled by triple expansion engines, the ships and engines of Cleveland manufacture. The high pressure cylinders of these engines are 24 inches diameter, the intermediate 38 inches, and the low pressure 61 inches. The stroke 42 inches. Revolutions per minute 85. Boiler pressure160 lbs. The data gathered from the record of three ships, each of 1100 indicated horse power, showed that an amount of fuel costing one cent is sufficient in actual practice to transport one ton of freight 110 miles.

With such results accomplished, may not the Mechanical Engineer say it is enough? Not yet. He says rather, if Compound Engines are good and triple expansion better, may not quadruple expansion excel them all? On this line, his most notable advance in Marine Engineering has been made.

It is well known that the quadruple engines have been used already quite extensively; in fact, they were introduced shortly after the triple engines, and some of the foreign builders, notably Wm. Denny of Dumbarton, have been strong advocates of their use; but in this country, on the coast and on the lakes, except in a few cases, such as steam yachts and torpedo boats, like the "Cushing" and "Say When," their adoption has been brought about by a desire for a large power in a limited space.

The new Inman Line twin screw steamer, building at Philadelphia, and the new twin screw steamer for the Great Northern S. S. Co., building at the Globe Iron Works in this city, are two notable examples of the adoption of the quadruple expansion engines on an extensive scale.

Of the Inman Line, there are four ships 510 ft. over all, 64 ft. beam, by 45 ft. deep. The dimensions of the engines are 36 in. diameter for the high pressure cylinder, 50 inches for the first, and 71 inches for the second intermediate, and 100 inches diameter for the low pressure, by a stroke of 5 feet, and they are to make 90 revolutions or 900 ft. of piston travel per minute. There are six steel boilers 15 ft. 7½ inches diameter by 20 ft. length. The shell plates are $1\frac{9}{16}$ inches thick, to carry a working pressure of 210 pounds per square inch.

Of the Great Northern Steamship Line, there are two ships 383 ft.

over all, 44 ft. beam by 26 ft. deep, and the dimensions of the engines are 25 inches diameter high pressure cylinder, 36 inches for the first and 51½ inches for the second intermediate, and 74 inches for the low pressure, by a stroke of 42 inches, to make 120 revolutions per minute, or 840 ft piston travel, and to indicate 3500 H. P. each engine. Steam is generated in Belleville water tube boilers and delivered to the engine at 210 pounds working pressure. The adoption of the quadruple engines is expected in these cases to effect a saving of 20 per cent. These were designed by Mr. Walter Miller, one of our own members, and are expected to be completed in season to inaugurate the fast line from Buffalo and Cleveland to Duluth next year.

The Mechanical Engineer is not content with these results, but has studied so carefully the best methods of reaching them that the best engines of to-day are built at much less cost than the poorer ones of a short time ago. This important phase of mechanical engineering is made manifest in nearly all kinds of manufacturing.

The improved methods and machinery in use at the Baldwin Locomotive Works enable them to turn out 1200 locomotives per year. On a recent visit to those works, the writer saw a long row of nearly completed locomotives, side by side in the assembling shop. It was desired to take out one of them, and to do so, the traveling electric crane came along, and by the manipulation of one man, took a 90 ton locomotive and carried it over the tops of the others to the track from which it was to be sent to its destination. One practical person on being told that the Baldwin Works were making four locomotives per day replied, "It is impossible, for there wouldn't be time for the paint to dry!"

The work of the Mechanical Engineer at the Homestead Mills so greatly increased the production that workmen comparatively unskilled were making, by the old scale of wages, sums ranging from $300 to $600 per month. The fact that the Company making these improvements wished a share in the benefits, occasioned the re-adjustment of wages, which brought about the strike last summer.

Our latest types of steel works are planned to take the ore into the furnace at one end, and before it is cold, transform it into the finished steel rail or structural beam, ready for the market, at the other end of the mills.

The handmade goods so strongly preferred a quarter of a century ago are no longer called for, for the superiority of machine-made articles in nearly every line is acknowledged by all.

A marked result of careful mechanical engineering is shown in the manufacture of watches. In the most severe comparative tests, ranging in temperature from the refrigerator to the oven, the record of the American machine-made watches far surpasses the best hand-made watches of Europe, while the cost of production is so far reduced that

a high grade, compensated movement, with 15 jewels, can be bought at retail here in Cleveland for $15.

Cottons, woolens, and all clothing materials are so reduced in cost by the best mechanical appliances that the workingman can afford to dress as well as the capitalist, and clothes are no longer an indication of social position.

We might multiply illustrations through the whole line with similar results. The field is large and continually growing and presents the most encouraging outlook for the student; for tne young man who can think and act in advance of his fellows, and lead others to think and act, is wanted all along the line, and the capable Mechanical Engineer of to-day is commanding the highest remunneration for the use of his talents.

Our excellent technical schools, of which Cleveland possesses one of the best, are doing much to supply the urgent demand for educated, thinking Engineers, and we may expect a continuation of the wonderful progress which this engineering age has given us.

The effect of all this as manifested to the people, is that a day's labor in any line will purchase more than ever before, so that articles which were considered luxuries but a few years ago may now be possessed by all energetic workers.

PRELIMINARY SURVEY FOR ELECTRIC LIGHT STATIONS.

By E. P. Roberts, M. E., Member Civil Engineers' Club of Cleveland.

[Read July 13, 1893.]

When I began to prepare this paper I was reminded of the excellent paper we heard from Mr. Ritchie at the last meeting, with reference to the use of the stadia method for Preliminary Surveys for railroads and the obtaining by same a bird's eye view of the situation enabling the comparative value of different locations to be more readily compared.

My talk this evening will be, as it were, the application of the stadia method to Preliminary Survey for an Electric Light and Power Plant and thereby obtaining a general grasp of the situation.

The importance of preliminary survey in electric light work, as in other lines of engineering, has not always been sufficiently considered. It is quite a simple matter to design an electric light station that will give light; but to get the one that is best for the special conditions is quite another thing. It necessitates looking into the present conditions and considering the probable growth of the city, and also considering

the different sites and all matters which would naturally affect the electric light plant, such as the price of gas, etc. and in addition, the general character of the apparatus which can be best installed: and finally working out several plans in detail as to cost of erection and opertion, and income probable and possible.

First of all to get an idea as to the present needs of any plant, it is easy to hear about a town, and say "for that number of inhabitants and character of town there will be so many lights needed per capita," etc. "If gas is $2.00 per thousand in the town, and the stock only slightly watered, you may have to compete with that company at $1.25 or $1.50 per thousand, and probably have to compete with it at the same price per candle power." From such a very rough way of figuring proceed to dynamo capacity and the division of the dynamo, and steam engine units, etc. The best station cannot so result but it is not unusual that stations for small towns are designed by the company's "expert," from a map and the salesman's report, assisted (?) by the

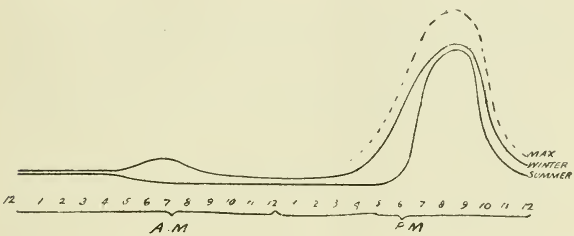


FIG. 1.

salesman's effort to have the plans in accordance with the idea of Mr. ——— of the committee. The first thing to do is to go to the town and become acquainted with the habits of the people, and ascertain whether it is an agricultural, manufacturing, mining, or commercial town, and size it up in a general way.

The next point is to determine the "output diagram" and this is best done by tabulating the various classes of customers, the probable number of lights each class will use, and the use of the lights for each hour of the day and night, and then, by adding the results together, the curve representing the average winter and summer outputs for lighting purposes can be obtained and the probable maximum output for Saturday evenings and special occasions be also shown. Curves having the general appearance of those shown in Figure 1 will result. The next point is to determine to what extent current for power and for heating can probably be furnished, and add such results which will probably help to fill in during the time of light load.

If power is to be furnished by the same dynamos as those furnishing light, the problem of distribution and of dynamo units is, in some respects, simpler than if the contrary be the case.

From the curve the size and number of dynamos and engines can be determined, keeping in mind the matter of growth, etc. Although it is necessary to consider the maximum load it is the designing for the minimum and average load which shows the skill and experience of the engineer, and it is the obtaining loads for the time of light load, which taxes the ability of the manager. From the tables can be computed the income per light installed, for each class of customer, and the income per H. P., installed, based on power used at time of stations maximum load. From these can be determined the comparative value of various classes of customers. It is seldom that $\frac{1}{3}$ the total incandescent lights in residence districts are used, or $\frac{3}{4}$ those in business districts, $\frac{2}{3}$ to $\frac{3}{4}$ is the usual proportion of dynamo output to incandescent lamps in place.

Arc lamps are generally all in use during the early evening. It is generally best first to figure incandescent lamps, on the basis of 1 cent per lamp and 10 to the H. P. These being decimal figures, a percentage can easily be added or substracted if desirable, and are a fair basis for most places. When incandescent light is less it is generally at a loss, unless special conditions exist to make the generation less costly than the average.

The report of the Massachusetts Board of Gas and Electric Lights company states that many Mass. companies find that they must raise the rate from $\frac{3}{4}$ to 1 cent and $1\frac{1}{4}$ cent in order to pay a reasonable dividend. 1 cent for a 16 C. P. light is the same as $2.00 for 16 C. P. gas, nominal (450 Watt) arc lamp. The result may be an income of $8 to $10 per year per incandescent lamp installed and $75 to $125 for 2,000 C. P.

Having determined on the output desired for immediate necessities and not for the distant future it is necessary to design the station to produce the same as economically as possible. Options must be obtained on several sites and their comparative advantages and disadvantages carefully weighed and, as the character of machinery installed may be very different for different localities (D. C. or A. C. dynamos, condensing or non-condensing engines) it is necessary to sketch out in considerable detail plans and estimates of erection and operations for two or more stations. Quite probably one location may even make possible a source of income, such as steam heating, which would not exist in others and this further complicates matters. Wherever the station is located provision for growth should be made and the plan so arranged as to make growth fit in to the original design. As noted above, the location of the station may decide the character of machinery to be used, that is D. C. or A. C., but the output curve and whe-

ther motors are to be used will have much bearing. If A. C. be used there is decreased efficiency of converters under light loads, whereas if D. C. be used the line loss is lessened under light load. Of course, the line loss for A. C. light loads also is bettered but it is generally a less percentage loss for D. C. and there are so many matters to be taken into account that an enumeration with explanation would take all night.

It is not difficult to design a station which will work, but probably enough has been said to indicate that to design the best station is not a simple matter and takes time. Unfortunately clients think such time is wasted and they are not disabused of this idea by many salesmen of electric light apparatus, which is natural as they, generally speaking, stand a better show of selling their goods, especially such sizes and character as they especially want to or think they stand the best chance of selling, if they, and not an engineer, do the work of designing. They are not to be blamed.

For elaborate tables of the above kind I would refer to some articles I wrote for the *Electrical World*, and published March 5 and 25 and April 22nd., of this year.

Even isolated plants such as for large buildings should receive considerable care in "Preliminary Survey." I will pass around curves showing the summer and winter loads for an office building, and for which the coal consumption is worked out in case one or two engines be used; they show sufficient saving in fuel to pay a dividend on additional cost, the second engine, irrespective of questions of reliability. The load from 10 P. M. and during the summer days, is light for any possible economical arrangement of engines and dynamos and, therefore, I have advised my clients in this case, to either burn gas for the load after 10 P. M. or to make arrangements to switch on to the commercial circuits of the city plant or to put in storage batteries, under rigid specifications and guarantee, to take care of such loads. This is a field for the storage battery, which I believe it will soon be called in to fill.

I regret not having more material to show you and not having my papers with me, but being a midsummer meeting, perhaps you will excuse me.

DISCUSSION.

THE CHAIR: Although this subject of electric lighting is only in its infancy at present, still it has already grown to marvelous proportions. We all remember what a short time it has been since the first electric lights were started and made a success of; and, doubtless, very crude estimates were made in those days. But it is coming nearer to an ex-

act science, and more attention is given to it because of the necessity of providing for possible contingencies, and for the purpose of saving capital in order that good returns may be had on what is to be invested. Like everything else: it has got down to getting the most light for the least money.

MR. HERMAN: The electrical engineers certainly share the fate of all the other engineers, Few investors are, as yet, ready to admit that preliminary work pays. They are in a hurry to see results. They are pretty much like the pattern maker who was nearly buried in shavings within an hour after he received a drawing, while another at his side did not seem to be doing anything, though he studied the drawings. However, the one that spent his time in studying the drawings before he commenced to work achieved better results in less time than the one who made the most shavings in the start. I would ask what is approximately the first cost of a storage battery for the storing of one horse-power per hour, and how much space would such a battery require?

MR. ROBERTS: I am not so familiar with the present prices of storage batteries that I can answer that question off hand, but I think I can get pretty close to it by figuring. While some one else is talking I will try and make some figures. We are not all aware of the fact that Professor Langley has been making a very extensive test on storage batteries. I hope you will get a great deal of information out of him.

PROF. J. W. LANGLEY: Perhaps I can answer the question in regard to size of batteries. A cell 9 × 10 × 4 was practically put out at the rate of $25. to $30. It would take about fourteen to maintain a city of that size. Of course, this is only a rough statement. A great deal depends on the rate you draw it out at.

MR. ROBERTS: If I mistake not, the old price used to be thirty dollars ($30.00) for the horse-power hour capacity. I understand the present price for a 150 Ampere hour cell is about $12.00 which would make above figure for one H. P. for one hour.

THE CHAIR: It has always seemed to me that one of the fields to be occupied by storage batteries in the future, perhaps as promising as any, is in equalizing up the power as suggested by Mr. Roberts: that is using a storage battery the same as we use a storage reservoir in water works. When there is no current to be used from the line, let the storage battery take the full force from the dynamo, and let the current be turned on when needed, the same as water is turned on from the reservoir. I think that has been tried in lighting cars. In stopping a train, the attempt has been made to convert its motion into electricity: store this till wanted, and then afterward use it in lighting the cars. This is not yet a success, but I hope it will be in the near future.

and that storage batteries will come in to supply large currents for short intervals of time, so that small engines, working a longer time and at full capacity, can supply a large or small quantity of electricity without material waste.

Mr. Skeels: I would like to ask whether storage batteries are not used more in Germany than anywhere else; and I would like to know the cause of it.

Mr. Roberts: I happened to drop incidentally into the matter of the storage batteries, but it seems to be taken hold of more than one or two other things I have said. I think I have twice talked of storage batteries in the Club, and the matter of its being used more in Germany came up at one such time. It was said by a member that they had better electricians there than here, and that they were cheaper.

Mr. Herman: What I said was, the good electricians are more plentiful in Germany, and considerably cheaper than here.

Mr. Roberts: I stand corrected. I have had an unfortunate experience with storage batteries, and it does not make me want to take it up again for general distribution. But for such a place which I have passed around this evening as the diagram shows, I am perfectly willing to give the opportunity to those who will guarantee results, because that is a place where it will pay if it ever will pay, and it is different from electric light stations. If we can save the day load so much the better. In an office building it would make no difference as to about the day load, because the engineer is there, and steam has to be used to run the elevators as a general thing. They have steam up six months a year in order to do heating, and may have it all times during the day time. A good thing is to take care of that load after eight or nine o'clock in the evening when the engineer has gone away. That is a great opportunity for the storage battery and it will be used in large office buildings.

Prof. Langley: Could a battery stand a loss of 50 per cent?

Mr. Roberts: Yes, and more. The first thought is often to put money into one dynamo and engine, and for nine-tenths of the time that engine and dynamo would be operating under a load varying from one-fourth to one-tenth of full load taking from 40 to 70 lbs. of steam for 1 indicated H. P., and from 50 to 100 lbs., or more for each electrical H. P., delivered.

Mr. Palmer: In power stations located some distance from the center of distribution, perhaps a mile or two, would it be advisable to have a storage battery near the center of distribution? Would it not be more trouble to go after it than to have it in a station?

Mr. Roberts: There have been two or three systems proposed; one is having the storage battery near the place to light, the other is having sub-stations and the other is to have them at the main station. Of

course they cannot be at the main station unless a constant potential system of D. C. mains radiate from the main station. If the lights are far away, having sub-stations is better. The storage battery is unfortunate in not being over compounded. You have to increase E. M. F. at your source as the load increases. You have to raise your E. M. F. from one to ten per cent. as you turn the lights on. The storage battery works the other way. It drops; and the automatic methods are quite complicated, and do not always prove reliable in the way of throwing on additional cells as the load increases. The dynamo is raised automatically, unless it is a station on the Edison system where they are raised by hand power. But some one has to attend to it. Also some one must give to all storage batteries constant supervision.

Mr. Herman: The matter of accumulating energy for the purpose of equalization of out-put is one of the oldest questions of engineering. Every dam that is created to retard the flow of water serves this very purpose, and this has been used to drive water wheels as far back as history goes. In different branches of engineering this accumulator has been used right along. A very ingenious application is found in a late example of high duty pumps. A peculiar arrangement of auxiliary pumps is so attached to the piston rod that when the steam is at full pressure, these pumps force water into an accumulator; and when the steam expands and its force becomes less, these same pumps act as hydraulic motors and assist in overcoming the load. It has always seemed to me that accumulation of energy in connection with dynamos could be accomplished by mechanical means, somewhat as it is done with hydraulic presses, or in the case of compressing air, for less money and with better efficiency and greater durability, than with the secondary battery.

Mr. Roberts: Some time ago, some members of the club who are not here this evening, had occasion to say something about steam engines, and expressed surprise that electrical engineers had special knowledge of steam engines. I think what I have said this evening shows the necessity of a knowledge of the economic use of steam. It is curious that two of the most valuable contributions during the past winter in the matter of how to use steam most economically have been before the American Institute of Electrical Engineers. A great deal of such work, and probably more and more as we are getting more toward the engineering side of it, will be taken up by the electrical engineers. The point I wanted to bring out more especially this evening was along the line of the necessity of preliminary survey. I had in mind somewhat the paper which was read here at the last meeting, about stadia surveying, and the opportunity it gives for locating the exact line before the final location is decided upon. Careful preliminary study before the final grasp can be obtained is advisable from a standpoint

of dollars and cents, and time should be taken to do this.

Mr. Palmer: One more thing might be considered, and that is the use of water power. Some time ago I saw in an article that $^9/_{10}$ of electric light stations using water-power were paying dividends, while almost as large a proportion of those using steam engines were not. If you have to use steam power the chances are that your electricity will cost you as much as you get for it; whereas if you can use water-power at all, you can make a good thing out of it.

Mr. Roberts: There are a few places where water-power pays and many places where it does not. I know that some places where water-power has been used and where they pay dividends they charge high prices. Water-power is used somewhat in New England; on the other hand the cotton mills in New England, where water-power has been used, find according to papers read before the mechanical engineers, that in many cases it would pay better if they had steam power and had not invested in water-power, but they do not want to change. The necessity of having a steam plant in order to help out is very general. Next week I am going to a place where they want to consider using a water-power for a small portion of the year. I do not know what the decision will be. I do not mean to say that water-power is never advisable, as sometimes it is. But it is not always perfectly satisfactory. Where water-power can be obtained at a small expense it is a great assistance.

Mr. Herman. As long as thirty-two years ago in the first position I had after leaving school I was engaged in tracing a steam engine of a paper-mill, which had a great abundance of water-power, but was not reliable. Sometimes there was so much water they could not use it. I have seen the same thing since then. Water-power is very expensive where there is anything wrong, and it is not reliable. Steam power, in my estimation, is cheaper.

THE DISPOSAL OF SEWAGE.

By S. A. Mitchell, Member, Engineers' Club of Kansas City.

[Read April 10, 1893.]

The subject as announced for the paper this evening, "The Disposal of Sewage," is one of interest and vital importance to every community. A subject which the Engineer has been called upon to adapt to such a variety of conditions that it has become broad and far-reaching in its significance, embracing as it does, the various systems of collection and treatment, as well as the final disposal of sewage.

Of the systems which have been adopted and found more or less satisfactory and economical, we find systems of Intermittent Filtration, Porous Carbon, Broad Irrigation and Chemical Precipitation. Upon these there is already extensive literature, but I have chosen to confine my paper to the disposal of sewage in Kansas City.

In so doing I will not presume to submit anything new upon a subject which has been before the people in all its varied phases for so many years, that every feature has become familiar with the Engineer and in fact nearly every citizen can confront you with a theory of perfect sanitation and proper drainage for home and City. And yet the citizen's theory serves equally as well as the Engineer's plan, which only submits glittering generalities, bold in their conception, yet impracticable in execution.

As a preface to the discussion of the method of disposal of sewage for Kansas City, I will review briefly the history of the system which makes some system of disposal necessary.

The present system of 107 miles of District Sewers and ten (10) miles of Public Sewers has grown to this extent from a few disconnected culverts, which in early days afforded a crossing of the Main Street Ravine to the Freighter's train as he followed the winding trail between the river landing and the trading-post at Westport.

Just how these culvert structures of the early fifties combined the massive log and masonry construction, I will have to leave for some of our older members to recite, along with their "Before the War" stories. But prior to 1860 the records have only preserved to us one item of expense against our sewer system, that being $500. for constructing a culvert, now part of the Main Street Public Sewer. While it can be said that sewer construction was begun in 1865, when the city only had a population of 5,000, the work was for five years, confined to the Main and Walnut Street Public Sewers, amounting practically to culverts and not until 1870 when the population had increased to 32,000 did Kansas City begin to provide for house drainage by districts sewers, payable in special bills of assessment, nor during the succeeding ten years from 1870 to 1880 did the city make any great strides toward providing sewers, for during this period there were only eight district sewers constructed, so that in 1880 our City presented to the Engineer a population of 63,000 people and an area of 2,907 acres, with district sewers amounting to less than one and one-half (1½) miles and less than two miles of Public Sewer.

That the people began to awake to the vital importance of sewer improvements is shown by the record of the succeeding five years which is as follows:

Prior to 1880		1.4 Miles,	Cost	$38,171
1880	District Sewers	1.97 "	"	47,651
1881	" "	3.72 "	"	74,592
1882	" "	4.8 "	"	76,945
1883	" "	7.1 "	"	123,324
1884	" "	6.8 "	"	157,646
	Public Sewers	3.21 "	"	116,512

Total length of sewers in Kansas City, January 1st, 1885,

25.8 miles of District Sewer, at a cost of $518,329

3.2 miles of Public Sewer, " " " " 116,512

During the next succeeding five years we find the record of construction as follows:

			COST.
1885	Public Sewer	.35 Miles	$11,455
1886	" "	1.1 "	40,610
1887	" "	.45 "	24,098
1888	" "	.8 "	25,337
1889	" "	.46 "	10,686
		3.16	$112,186
1885	District Sewers	16.2 Miles	$273,415
1886	" "	6.2 "	106,096
1887	" "	8.48 "	44,796
1888	" "	26.5 "	306,826
1889	" "	21.7 "	211,308
		79.0	$1,042,641

Thus making when our city had reached a population of 134,000:

The total of Public Sewers, 6.4 miles at a cost of $228,698;

And the total of District Sewers 104.8 miles at a cost of $1,534,620.

The above statement will show that while we made rapid progress in our system of District Sewers, when we recall that out of a total area of 8,435 acres in the city, there yet remains 3168 acres without sewerage, not only the Engineer and Sanitarian, but every enterprising and thoughtful citizen is impressed with the imperative need of some active measures toward securing additional drainage. But if the city wishes to boast of being a well drained, thoroughly sewered city and expect the enforcement of her sanitary laws, she must provide a suitable and effective outfall or other satisfactory method of disposal for her sewage. Toward the solution of this question we find that topographical conditions and the location of our city has afforded valuable assistance. Nature has provided us with the most economical of all methods of disposal, the swift waters of the Missouri River, leaving

the one question to confront us, what method shall be adopted to conduct our sewage to the River channel?

Believing that there can be no question that the combined system is the one best adapted to adequately meet all of the demands for the larger portion of our city, I think a point was reached where a judicious combination of this with the system of interception was essential. The manner in which this combination should be effected, first presented itself in the treatment of the sewage of the O. K. Creek Valley. Here the engineer found himself confronted with the most interesting as well as the most important questions for the proper sewerage of our city; an improvement affecting the entire city and involving the expenditure of such large sums, should be metropolitan in its conception. comprehensive in its nature and economical in its execution. That the improvement has been one of piece meal, faulty location and temporary expedient, not founded upon a far sighted or well defined plan, must be admitted by any one who will study the problem in its present condition. As to economy or equity of the plan adopted, I will leave the figures which follow to show.

That the point where the principle of interception should be applied to our combined system was reached some ten years ago, is evidenced by a strong and forcible statement in the report of the City Engineer submitted to the Common Council, January 1st, 1883, which says:

"There are many important Engineering questions arising in connection with the construction of outlet and intercepting sewers for carrying off sewage of the southern slope of the city along the valleys of O. K. and Turkey Creeks and also in connection with the drainage of West Kansas. The amount of money involved is large and the necessity for the immediate decision is pressing and the considerations as affecting public health are of paramount importance. The plan adopted for our city should be the one which is best and cheapest to fully meet all of the present and future requirements." This general recommendation resulted in the initial step of the improvement being taken. A survey and map of the entire water-shed of O. K. Creek was made and the general features for the construction of an intercepting sewer was outlined by the Engineer in his report to the Common Council the following year, January 1st, 1884. In this connection it might be said that when it is stated that "The amount of money involved is large" it is not so very large when placed in comparison with the amounts that other cities are called upon to expend on similar problems. We would hardly be expected to submit to a comparison with Chicago with her 180 square miles and one and one-half million of people, or with the City of Boston that can expend $4,250,000, on a trunk sewer and pumping works alone: but we ought to submit to a comparison with cities near our size: as such we might mention Tor-

onto, that has a very little larger area than ourselves and only 190,000 population, and yet they adopt a plan which involves the construction of two intercepting sewers, one serving an area of 8704 acres for the removal of sewage of a population of 300,000, is a sewer 7.2 miles in length, with the greatest diameter of eight feet. A second intercept designed to serve an area of 1429 acres and a population of 55,000 has an extreme diameter of only four feet and is 5.2 miles in length. The construction will require the expenditure of $1,632,518 while a comparison of amounts and all comparisons perhaps are odious, we ought to at least equal such cities in the conception and design of our general plans.

The first plan suggested for the city was in brief a sewer beginning at Seventeenth and Campbell Streets with a diameter of five feet, running thence west along the route north of and practically parallel with the creek, to a temporary outlet seven feet in diameter at the intersection of Twenty-fifth Street and Turkey Creek, the ultimate point of discharge to be the Missouri River, the sewer to be so constructed as to intercept the sewage proper and a small percentage of rainfall from all the main district sewers.

The report estimates the cost of such an interception sewer at $95,-000 and further suggests the straightening and improving of the channel of the O. K. Creek and closes by saying "that the construction cannot be longer delayed, excepting at the great peril of public health."

It would seem that such strong language and the evident necessity of the case would have aroused in a city of 90,000 inhabitants some active interest in so important a question. But the inactivity and seeming indifference of the average Common Council which can be said however, only to reflect the true feeling of a vast majority of the community, upon such questions and recommendations, may be cited as additional proof of what our president stated in his recent address, that "The position of the Engineer and the Engineer's Club and their influence was not what it should be in the community."

The average citizen and municipality will resort to temporary expedient and make-shift rather than consult an Engineer and perhaps go contrary to his advice after he has been consulted, and when they find themselves in a perplexing entanglement, they then, per force, seek his advice and complain if he proves to them that their short-sighted errors are most expensive to correct. That such has been the position of our citizens and municipal government toward the recommendations of their Engineers, is clearly shown by the history of the O. K. Creek Sewer.

Following the above report came equally as urgent recommendations from every succeeding Engineer for some active measures toward the disposal of the sewage of O. K. Creek Valley, but ten years have

passed, the city has grown from a population of 90,000 to 150,000, from an area of 2904 acres to an area of 8435 acres, and many of the added population have made their homes some place within the water-shed of this valley. The sewage from the more densely settled portions of the entire southern slope of the city has been emptied by the District Sewer outlets directly into the O. K. Creek Channel, there to be deposited along its shoals and irregular edges, to await a rainstorm to carry it on to Turkey Creek; but even this offensive and now mal-odorous condition during this entire period has only resulted in a piece meal policy of construction being carried out, each particular extension co-inciding with the particular whim of the Engineer in charge, or perhaps more correctly co-inciding and commensurate with the available funds and direct necessity of the case. That this has been the case and that no fully defined plan has been followed is plainly evidenced by the records and reports which show the growth of the intercepting Sewer as follows:

During 1884 the first section of the Intercepting Sewer was built from Seventeenth (17th) Street and Campbell Street to Nineteenth and Holmes Streets at an expense of $9,095; during 1885 the sewer was extended from Nineteenth and Holmes Streets with a reduced diameter to Twentieth and Locust Streets at a cost of $5523; during 1886 the sewer was extended from Charlotte Street to Forest Avenue at a cost of $9582; during 1887 the extension was continued from Forest Avenue to Vine Street at a cost of $2241, thus completing during the five years 5,724 feet of Intercepting Sewer at a cost to the city of nearly $27,000 and the Creek Channel still remaining so offensive that the city is compelled to construct Flush Tanks at an expense of $2,251, and appropriate an additional sum of $2,000 for the removal of lodgments along the creek and the improvement of its channel.

The above then will serve to show the applying or misapplying the principle of Intercepting Sewers to the disposal of the sewage of O. K. Creek Valley. The unsatisfactory results coupled with some very cogent reasons and the conviction that the Public nor property owners would be permanently satisfied with any plan of open channel," led the succeeding City Engineer to recommend "The abandonment of the plan for Intercepting Sewers in the territory lying east of Baltimore Avenue, and the constructing of a main O. K. Creek Sewer for both sewage and storm water."

The plan suggested was comprehensive in design, definite as to the route and size of sewer and estimated at a cost which subsequent facts have practically verified as correct, but the city government was equally as indifferent to this recommendation as they were to the previous one for the Intercepting Sewer, and not until three and one-

half years later did the city authorize this much needed improvement and make the necessary funds available.

But when the citizens authorized the city to incur the necessary expense to protect their health and improve the sanitary condition of the city by the proper disposal of their sewage, it does not follow that they authorized the city to reclaim for the benefit of private citizens property valued at $150,000 to $200,000, by providing in its streets a water-way for such streams as may be found coursing their way through the limits of the City. But such is the plan the city approved and saw fit to adopt.

That such a method of disposal for the sewage of O. K. Creek Valley will serve the greatest good to the greatest number, and obtain for the city an improvement sanctioned by the principles of economy, the best Engineering and Sanitary Practice, is a question which certainly invites discussion.

Viewed in the light of Sanitary Science the Engineer is familiar with the many advantages the separate channel for conducting sewage proper, has over the combined system.

It is not the object of this paper to discuss these features of the question, but as to the economy of the plan and its justice and equity to the citizens, I may be able to present some facts and figures with which you are not acquainted.

The plan which was adopted and approved in 1890, only covers the territory lying east of Grand Avenue, including a route 10,078 feet in length. This is only a trifle more than one-third of the length of the entire distance to the Missouri River, and yet when this section is completed, it would have cost the city nearly $225,000 or more than $22. per foot.

Had this plan been continued, even as far as Turkey Creek, with this price as a basis, the sewer, to this temporary outlet, would have cost $360,000; add to this an intercepting sewer to the Missouri River and your system of disposal for the sewage of O. K. Creek would have cost one half million dollars.

In addition to this the plan has rendered useless the Intercepting and portions of other public sewers, which cost the city $30,000; it requires the extension of other public sewers and terminates upon private property, with an outlet three feet lower than the present creek channel. Such conditions force the continuance of the present combined plan at least 2,000 feet farther, before a point is reached where it is practical to intercept the sewage proper. But if this be done and the storm water is abandoned to find its outlet along the creek channel, will not the citizens who own property along the creek have just cause to complain "that they helped to pay for reclaiming the low lands on the upper creek why should not the city continue their

policy of reclaiming land, by continuing the main sewer."

Again the city by assuming to care for O. K. Creek, must now be liable for any damages, from extraordinary storms, when the sewer may be found inadequate to carry the volume of water.

These are a few of the conditions which occur as disadvantages of the plan adopted.

It has the advantages of dispensing with a most unsightly creek and of releasing the city from the cost of maintenance of Bridge crossings at all the streets and alleys.

It would seem that the consideration of such reasons would force upon the mind the conviction that the proper and most economical method of disposal of the sewage of the O. K. Creek Valley was one Intercepting Sewer so located as to intercept the sewage proper from both slopes of the valley. If the city wished to improve the creek channel at the same time and construct permanent water-ways at all street and alley crossings, a thing much to be desired, a combination of the two improvements would have been economical and advantageous for both. By placing our intercepting sewer along the present creek channel it would have been accessible from both slopes, would not have rendered useless the present main district outlets and would have given the least amount of cutting in construction. By straightening the creek at a few points, building a brick or stone invert and carrying up substantial side walls to a height sufficient for an adequate discharge capacity during extraordinary storms and by adding parapet walls and arches at street and alley crossings, we would have had equally as permanent a construction as the present under-ground sewer, and a much less expensive one, with the advantages that the city would be free from the liability for damages from floods, would not have reclaimed land for certain ones at the expense of and to the disadvantages of others, and by this method both the flow line of the creek channel and the intercepting sewer, could be raised and by so doing insure a self cleaning sewer through West Kansas to the Missouri River, and render useless a system of maintenance found essential in large sewers.

That the conditions must be met as they now exist, the work of disposal continued by intercepting the sewage as soon as practicable and carry it to the channel of the Missouri River, seems to be the only solution for the speedy and final disposal of the sewage of the O. K. Creek Valley.

The second problem of sewage disposal in our city presented itself when the channel of the Missouri River shifted so as to leave three of our West Kansas Sewers, as well as two of the Kansas City, Kansas, sewers practically without any outlet. The sewage discharging into a long flat slough, hemmed in by a sand bar, soon made its fragrant pres-

ence known under the summer sun, and the question of Sewage Disposal became one of importance to the citizens of West Kansas and the travelling public that patronized the Elevated Railroad. It claimed the attention of the City governments of Kansas City, Kansas, and our own city during the past two years. It was met by the City Engineer of Kansas City, Kansas, by an extension of one of their sewers to the river channel some 1000 feet at a cost of fourteen or fifteen dollars per foot. They contemplated extending their second sewer in a similar manner, at an expense of $26,000 when Kansas City came to their assistance by recognizing, as the municipalities were one commercially, there should be no sanitary boundary line between them and gave them an outlet for $7,202 which would have cost them $26,000; but by so doing Kansas City was also benefited by thus obtaining an intercepting sewer half a mile in length for less than $8,000, which not only afforded the disposal of both the sewage and storm water from her three sewers and relieved a most distasteful and unhealthy condition, but also aided very materially the reclaiming of a large tract of valuable land.

The question of disposal has also presented itself in connection with the eastern and northern slopes of our city. The eastern slope with an area of 1232 acres must for the present accept the natural drainage course, or Goose Neck Creek as a means of disposal, with a view of ultimately carrying the sewage proper in a closed sewer to the Missouri River. The objections which are raised to the use of Goose Neck Creek as an outfall for the sewage from that territory are not well founded and can hardly be maintained in the face of the evidence found in practice and the history of open channels which have been maintained for years in more densely populated cities than our own.

The northern slope and low lands of the east bottoms will present some features in the matter of sewage disposal which should receive attention, and the work inaugurated upon a comprehensive and fully detailed plan in time to avoid expensive re-construction. Already the shifting channel of the Missouri River has left the present outlets of five large sewers so far from the main channel of the River that their discharge has become so offensive and such a menace to the public health as to demand consideration. If such an evil can be remedied more economically by the plan of interception as practiced along the river bank in West Kansas, or by an independent submerged outlet for each sewer is also a question which invites discussion. The topography of the East Bottoms may suggest a high and low level intercepting sewer and also some system of utilization of sewage.

This briefly presents the question of Sewage Disposal which must be met for our city with its present limits; but growth in population and in addition of territory, as may be anticipated in the future, it may present some new features. But the general topography of the Brush

Creek and the Blue River Valleys is such that the question of proper Sewage Disposal will not be a perplexing or difficult one.

While most of the watershed of Turkey Creek lies beyond the jurisdiction of our city, the populating of that valley may result in the polution of Turkey Creek to such a degree as to demand the consideration from our city, and this in consideration with the pollution of Kaw River from the sewage of Argentine and Kansas City, Kansas, may call for a united action of the cities interested, upon some method of proper treatment of the sewage of both valleys to prevent the pollution of Turkey Creek and Kaw River.

The presentation in this very general way of the methods of sewage disposal necessary in Kansas City, will suffice to emphasize the conclusion, that it has not been economy or wisdom for the city to employ its "piece-meal policy" in the construction of so comprehensive an improvement. Had a will designed and detailed plan covering the entire problem been adopted and a strict compliance therewith been adhered to, in the building of each section, the city would not find itself in the position it now is, that of being confronted with the appropriate advice, "Be sure you are right and then go ahead."

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

CIVIL ENGINEERS' CLUB OF CLEVELAND.

SEPTEMBER 12TH., 1893. Meeting called to order at 8 o'clock by the President. 25 members and visitors present.

The record of meeting held on July 11th., was read and approved.

A letter was read from Mr. T. H. Young transmitting an invitation to the members of the club to attend the ceremonies in connection with "Railway Day" at the World's Columbian Exposition, Chicago, on the 16th., day of September.

Mr. Searles presented a report from the meeting of the Board of Managers held in Chicago during the first week in August.

Mr. Thos. D. West read a paper entitled, "Engineering the Establishment of Competitive Manufacturing Enterprises" which was discussed by Messrs. Ludwig Herman, John Walker and Jos. L. Gobeille.

Prof. C. H. Benjamin read a paper entitled, "Experiments on the Elastic Strength of Steel Hoops," which was discussed by Messrs. Osborn, Searles, Gifford, Langley, Herman, Walker and West.

Adjourned. FRANK C. OSBORN, Secretary.

OCTOBER 10TH., 1893. Meeting called to order by the President. 40 members and visitors present.

Record of meeting held on September 12, was read and approved.

The applications of Wm. C. Jewett, A. Lincoln Hyde, Frank H. Constant, John J. Schmitt and Henry Gray for active membership were read.

Mr. F. H. Richards, of Hartford, Ct., then read a paper entitled, "The Cam, and its Importance in the Modern Development of Manufactures," which was discussed by Messrs. Ludwig Herman, Prof. Benjamin, N. B. Wood, C. O. Palmer, E. P. Roberts, Prof. E. W. Morley and W. H. Searles.

Mr. W. H. Searles then presented some remarks on the "Ferris Wheel."

Meeting adjourned at 10 o'clock. FRANK C. OSBORN, Secretary.

WESTERN SOCIETY OF ENGINEERS.

305TH., MEETING, SEPTEMBER 6, 1893. The 305th. meeting of the Society was held at the "Engineering Headquarters," No. 10 Van Buren Street, Wednesday, Sept. 6, 1893, at 8 p. m. President Robert W. Hunt in the chair and 25 members and guests present.

The reading of the minutes of the last meeting was dispensed with.

Before introducing the business of the evening, the President called for a vote of the Society on the question of postponing the date of the October meeting to admit of the presentation of a paper by Mr. W. H. Jaques, for which it was impossible to arrange on the regular date.

Mr. S. S. Greeley moved: That the date of the next meeting of the

Society be made subject to the arrangement of the Board of Directors. Seconded and carried.

The President announced the death of Mr. Wm. Scherzer, member of the Society, which occured Thursday morning, July 20th., in Chicago.

Mr. Strobel moved: That a committee of two be appointed by the chair to prepare a memorial. Seconded and carried.

Committee: C. L. Strobel, August Ziesing.

President Hunt then introduced the business of the evening.—The entertainment of the delegation of French Engineers by the Western Society of Engineers,—and called upon Mr. Isham Randolph, Chairman of the Entertainment Committee, to explain what had so far been accomplished by the committee.

Mr. Randolph presented a programme covering the eight day's sojourn of the delegation in Chicago, and touched upon the exertions of the committee towards obtaining funds, etc.

The President further explained the financial and other conditions governing the entertainment, which rendered it necessary that some of the special features of the proposed programme should be confined to the care of committees, the members of which would defray their own expenses. At the same time, the credit for the hospitality would accrue to the whole Society. He also urged a general attendance at Engineering Headquarters, No. 10 Van Buren Street, at 10 o'clock, Monday, Sept. 11th., to welcome the Foreign Guests. The President also urged as large an attendance as possible at the evening Receptions in the Transportation Building on Thursday evening, and at Engineering Headquarters on Friday evening. On the former occasion the members of the Society and the visitors will be the guests of the Exhibitors in the Transportation Building, on the latter of the Committee of the United Engineering Societies.

After some further discussion it was moved and seconded: That the programme, as read, meets with the approval of the meeting. Carried unanimously.

Adjourned. John W. Weston, Secretary.

MONTANA SOCIETY OF CIVIL ENGINEERS.

June 24th., 1893. The meeting was called to consider "what action the Society would take concerning the articles that recently appeared in the daily press relative to the completion of the Great Northern Railway Extension to the Pacific Coast, and wherein no reference was made to Mr. E. H. Beckler's connection with that enterprise."

There were present: Messrs. Haven, Griffith, Herron, Cumming, Hovey, Kelley, Relf, Wheeler, Foss and Sizer.

The Secretary read a communication from Mr. Relf calling attention to the slight given to Mr. Beckler in the account published in the St. Paul and Minneapolis papers at the celebration of the opening of the Pacific Extension of the Great Northern Railway, June 7th. and 8th., 1893. While the work done by other men had been extolled, no mention had been made of the man who discovered and located the route through a wilderness, and to whose energy, more than to any other one man, the successful completion of the work was due.

A letter was also read from Mr. J. H. Ellison, in which he urged that the Society take some immediate action in the matter.

The Secretary then read a set of resolutions, which, after discussion,

were, on motion duly made and seconded, referred to a special committee appointed by the chair: consisting of Messrs. Griffith, Kelley, Herron and Relf. The committee were instructed to report to the Society such line of action as they deemed expedient, at the regular meeting in July.

The Society thereupon adjourned. G. O. Foss, Secretary.

JULY 8TH., 1893. Only four members being present, the meeting was adjourned for the want of a quorum subject to the call of the Chairman of the Committee, appointed at the special meeting held June 24.

G. O. Foss, Secretary.

AUGUST 12TH., 1893. The meeting was called to order with President Haven in the chair.

There were present: Messrs. Haven, Relf, Kelley, Hovey, Cumming, Keerl and Foss.

Minutes of June meeting, were read and approved. Melville E. Reed was duly elected to membership.

The Secretary was instructed to prepare and have printed, a new list of members, together with list of officers, and such other data as he might deem proper.

Mr. Kelley of the committee, appointed at the special meeting in June, reported as follows:

Mr. E. H. Beckler has removed from the State, and his connection with the Society as an active member, will soon cease. Mr. Beckler has shown engineering ability of great merit as Chief Engineer of the Pacific Extension of the Great Northern Railway, securing a route through the Rocky Mountains with lower gradients than any other transcontinental line, the maximum gradient east of the summit is one per cent; west of the summit 18 per cent.

The crossing of the Cascade Mountains, is made with a maximum 22 per cent. grade, and on a route so direct that the distance from Spokane, Washington, to Puget Sound, is shortened 94 miles over any other route.

The location for most of the distance was through an unexplored and mountainous country and the work of construction under Mr. Beckler's direction, was pushed in a manner heretofore unequalled in railway construction, and track laying over the entire distance of 818 miles was completed in a little over two years from the time construction work was inaugurated.

Your committee believe that Mr. Beckler is entitled to great credit as an Engineer, for the able manner in which this important engineering work was conducted, and we would respectfully recommend in view of the forgoing facts, and that Mr. Beckler is a past President of this Society, that he be elected to honorary membership.

The committee's report was duly seconded with appropriate remarks by Messrs. Relf and Foss, and on motion of Mr. Keerl, the Secretary was instructed to notify all members of the Society that the matter would be voted upon at the next meeting.

No further business offering, the Society thereupon adjourned.

G. O. Foss, Secretary.

SEPTEMBER 9TH., 1893. The President presided.

Present: Messrs. Wickes, Hovey, Herron, Wheeler and Keerl. The Secretary being absent, Mr. Keerl was elected Acting Secretary. The President stated that the special business before the Society was action

upon the nomination of E. H. Beckler, Esq., for honorary membership in the Society, such nomination having been recommended by the special Committee appointed June 24th., at the regular monthly meeting held August 12th., last.

Mr. Herron moved the election of Mr. Beckler to honorary membership in the Society in the following words:

"Mr. President:—

I take pleasure in nominating Mr. E. H. Beckler for election to honorary membership in the Society, and also in being able at this time to bear testimony to the personal worth of the man, we, as a Society, desire to honor.

He is known to all of us by the results of his energy and ability: but best known to some of us by that personality before which it was a pleasure to forget the dullness of daily routine and to look on work for its promises and possibilities.

I speak for myself and my associates, who. as subordinates, were connected with Mr. Beckler in his work, when I say that whether in office or in camp, in civilization or in the wilderness, he was the same, a leader always, but a leader men would follow because his counsel meant encouragement and his friendship was not limited to time or place.

The report of the special committee has mentioned his engineering achievements. "Let him bear the prize who merits it." That Mr. Beckler does merit the honor attached to his achievements, none can gainsay.

The energy that commands a great work to be done is entirely different from the energy that determines the best manner of doing the work. The result depends on the united energies: but in the glitter and pomp attached to the purpled chariots in their triumphal march the populace see only the energy that commands it.

This to a certain extent is natural, and happy is he who loves his work for its own sake and who sees his reward, not so much in the applause of the populace as in the assurance that his work is a part of "that philosophy whose law is progress," and of that civilization which has been advanced in this work of Mr. Beckler's, the spanning of a continent with its annihilation of distance.

It would be idle, Mr. President, for us to file a protest against the natural bent of human nature. its almost idolatrous worship of what we are pleased to call success. but it does seem to me eminently fitting this evening, that we, as members of the Montana Society of Civil Engineers, place on record, not only our conviction but our pride that the honor of these great engineering works belongs to a member of our own Society."

After appropriate remarks by the President and others upon the attainments of Mr. Beckler, upon a viva voce vote he was declared unanimously elected as an honorary member of the Society.

Regrets were expressed that action upon this matter had been so long delayed and upon motion carried, the Secretary was instructed to compile the remarks upon Mr. Beckler for publication in the Engineering Journals, the Local Press, and the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES, and to send Mr. Beckler a copy of same. The chair named the following as the nominating committee for the offices for 1894:

Geo. T. Wickes, Chas. G. Griffith and C. W. Goodale. Moved and carried that the representatives in the Board of Managers be included in the list of officers to be named by the nominating committee.

The chair appointed the following committee on topics for balance of year.

For October, 1893.	C. W. Goodale,
" November "	Geo. T. Wickes.
" December "	John Herron.

After an informal discussion upon general subjects of engineering interest, the meeting anjourned.

J. S. KEERL, Acting Secretary.

Editors reprinting articles from this journal are requested to credit both the JOURNAL *and the Society before which such articles were read.*

ASSOCIATION OF ENGINEERING SOCIETIES.

ORGANIZED 1881.

Vol. XII. October, 1893. No. 10.

This Association, as a body, is not responsible for the subject matter of any Society or for statements or opinions of any of its members.

MODERN STREET PAVEMENTS.

By O. B. Gunn, Member, Engineers Club of Kansas City.

[Read July 10, 1893.]

So much has been written and spoken, upon the important subject of street pavements, that perhaps the subject ought to be considered as well nigh exhausted, but as the lot owners, who have the selection of the material, and the election of the kind of pavement they deem best for their particular localities, and the kind of traffic it has to carry, and who have the burden of paying the bills, may possess but little information upon the subject, it would seem proper to give them a few points, which they may heretofore have overlooked, to aid them in their selection.

A paved street is constantly before the eye, and every man has the right to decide for himself, the kind of pavement he must pay for, as an abutting lot owner, and the kind he thinks best suited to his locality, and the condition of his personal finances; still before making a final decision, he should consider certain fundamental principles, which ought always to be taken into consideration, to aid in forming a just conclusion.

It might be supposed that we could gain much valuable information from the great commercial cities of Europe, some of which have been paved for many generations, but we find on investigation, that the cities of the Old World are in precisely the same condition as our own cities, in respect to pavements—that is to say, in a period of evolution. They evolved from earth roadways into gravel, then successively into McAdam, Telford McAdam, cobble-stone, and stone blocks, and

having reached the stone block era, for generations it was thought that this was the acme of all pavements, and nothing further could be desired.

As cities increase in population and business, the great centers become congested, and the streets become so crowded with vehicles of all descriptions, as to be almost impassable, and the constant, incessant, and intolerable noise, arising from the contact of millions of wheels and horses feet, with the granite blocks of the pavements, has become such a dreadful nuisance, and so irritating to the nerves, and aggravating to the temper, as to cause a general demand in the larger cities for a smoother and less noisy pavement, than that made of stone blocks. Accordingly, city governments, on both Continents, have been experimenting co-temporaneously for several years, with the same kind of materials as a means of relief from the great noise and roar, of the stone block pavements.

These new materials which have become great factors in the street pavement problem, are wooden blocks, vitrified brick and asphalt. They all have certain superior points over stone blocks and especially so in respect to noise, which perhaps is the greatest of the many objections to the stone blocks, and each of these new materials has its especial advocates.

In Paris it is claimed that sawed wooden blocks and asphalt are advancing in popularity; in London, asphalt is advancing, and wooden blocks at a standstill. In Berlin, asphalt is taking the lead of everything. We hear nothing of vitrified brick in either of these cities. In this country wooden blocks are receding in popularity, while asphalt and vitrified brick are rapidly advancing in public favor. In all directions, large cities are seeking emancipation from the intolerable noise of the stone pavement. Forty years ago, almost the only stone pavements in this country, were made of cobble stones. Durability was about the only merit they possessed; they would never wear out. In every other respect, they were simply abominable. They were dreadfully noisy, and would shake a carriage to pieces in a few months, and its occupants as well—but it would keep them out of the mud.

We evolved entirely and completely out of the cobble stone into the stone block pavement, and by evolution the stone block pavement will be relegated to the past.

As communities become more wealthy, and more æsthetic, they will look for, and find, a more desirable pavement than stone blocks. What the pavement of future generations will be, we cannot tell, for science and ingenuity may discover something far in advance of anything yet used for this purpose.

For the present we will only discuss those materials in general use in this country, viz:—stone blocks, wooden blocks, vitrified brick and

asphalt—leaving out macadam as only suitable for country roads and suburban streets, even where the best of materials are at hand, and much more, is this true, in this city, where available materials are scarcely fit for making a really good macadam street.

To determine what material is best for us to adopt, we must first decide what merits an ideal pavement must possess, and then consider what kind of pavement nearest fills the requirements of our ideal, and is best suited to the grades and traffic, where the proposed pavement is to be laid.

AN IDEAL PAVEMENT.

First:—It must be constructed of durable materials.

Second:—It must be as free as possible from noise.

Third—It must present the least resistance to traction—that is smoothness.

Fourth:—It must give the least wear and tear to vehicles and horses.

Fifth:—It must be easily cleaned.

Sixth:—The wearing surface must be practically non-absorbent.

Seventh:—The cost must be reasonable.

GRANITE AND SANDSTONE BLOCKS,

fill the requirements of our ideal in one respect, and in one only.

When well laid upon concrete foundations, they are durable. They are very noisy, and their rough surface gives the greatest resistance to traction. They cannot be well cleaned because mud and filth fill the innumerable large interstices between the blocks, and stay there. They give the greatest wear and tear to horses and vehicles, and discomfort to passengers. The blocks are nearly non-absorbent, but this is off-set by the moisture held in the filthy interstices, which when filled—as they alway are—become a part of the surface of the pavement, and it is the most expensive in cost, of all pavements.

Granite blocks have been but little used in this city, and most of our stone blocks are of Colorado sandstone. The cost of each is about the same, but the granite will give about 50 per cent. better and longer service than sandstone. The sandstone on Bluff Street and Union Avenue, laid about 7 years ago, is practically worn out, and needs a thorough overhauling and resurfacing, with a large proportion of new rock, which ought to be of granite—or better still, to give place to a new and better pavement.

The roughness of stone blocks is a great resistance to the hauling of heavy loads over it, and also causes a very great wear and tear to vehicles, and more especially after it is worn, and is allowed to get out of repair. I believe that as compared with asphalt, it takes 25 to 50 per cent. greater power to haul a given load over it, with three times the wear and tear to vehicles and five times the noise. It is impossible to compute the difference, but it would not be surprising, if these items

of extra wear and tear, and extra power to haul a given load, would amount in a term of ten years, to half the cost of the original pavement. This is far from our ideal pavement, and must inevitably give place to something better.

Fortunately we have only 2.38 miles of stone block pavement in this city, and nearly all of this is in the wholesale district in the West bottoms, where nobody is much disturbed by the noise except those who are obliged to do business there, and those would doubtless be very glad to get rid of it, as a whole-sale merchant said not long ago, that the noise in front of his store was so annoying that he would rather pay for a cedar block pavement every three years, than to have a stone block pavement for nothing. Doubtless most of these pavements will give place to something less noisy before many years.

WOODEN BLOCKS,

have come into use during the last forty years; they were first introduced by Samuel Nicholson of Boston, by the construction of a sawed wooden block pavement, that bears his name. 20 years ago, the Nicholson pavement was in quite general use in cities where lumber was abundant and cheap, notably Chicago and the cities of the North-West. They were composed of sawed blocks, six inches deep and four inches thick, set close together, ranging from curb to curb, each layer separated from its neighbor, by a half inch space, which was filled with coaltar and gravel. The material and construction were so cheap, and the decay of the pine blocks so rapid, that the Nicholson pavement was generally superseded, by the round cedar blocks, of which we have so many miles in this city. The Paris and London wooden block pavements are laid with creosoted or otherwise prepared wood, very much after the Nicholson plan. They are laid in the most thorough manner, are kept in perfect repair, and give excellent satisfaction, although the cost of repairs is greater than the repairs of any other pavement, and this will doubtless cause them to gradually yield to asphalt, as they have already done in Berlin, and are doing in London.

The cedar block pavement possesses several of the merits of our ideal pavement; it is almost noiseless, it is easy upon vehicles, and probably the easiest of any pavement, upon horses. When new, it is smooth and easily cleaned, but it is a great absorbent of moisture, and subject to early decay. It is the cheapest of all our pavements. When allowed to get out of repair, as it is in this city, and the interstices are enlarged, by the decay of the sap wood, it becomes filthy and cannot be well cleaned. Many claim that it is a dangerous pavement, from a sanitary standpoint, and that the exhalations from a decaying wooden pavement, are very harmful to health. It is doubtful if this theory can be substantiated, for with 50 miles of wooden pavement in this city, now in various stages of decay, the public health seems to be in

its usual excellent condition. Many declare that it is a worthless pavement, and ought never to be laid, but this position is untenable. Its advocates have never claimed for it a life beyond eight years in this climate, and the records of its life in this city, are fully up to the standard. The cedar block pavement, which lately gave place to asphalt, on Main Street, had been laid nine years, and the same kind of pavement on Broadway from 5th, to 16th, street, is now doing fair service in its 10th, year, and these are not isolated examples. As a pioneer pavement, it has been of great service to this city, many miles of streets have been paved, which but for the cheap cost of this pavement, would not have been paved at all. Doubtless as vitrified brick has come into general favor, since our cedar block pavements were laid, and can be put down for 20 per cent. greater cost, that very few, if any of our streets will hereafter be paved with cedar blocks.

Very little expense for repairs has ever been put upon the cedar block pavements in this city.

Probably cities like St. Paul, Minneapolis, and especially Chicago, where cedar blocks and pine lumber are cheap, and where a cedar block pavement, laid upon 2″ plank, costing about 1.15 per square yard, lasts about ten years, that this kind of pavement will be used and for a long time. Chicago is growing so rapidly in population and area, that a cheap kind of pavement seems almost a necessity.

VITRIFIED BRICK,

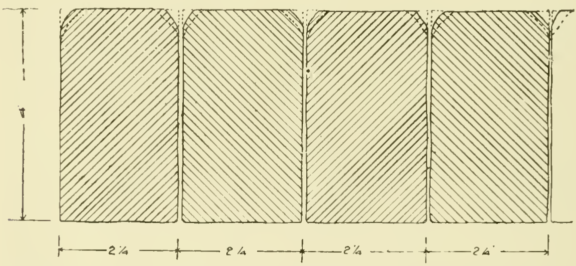
is the latest paving material, soliciting public favor, which is now on traial, with a fair prospect of its becoming a prime favorite. It possesses several of the merits of our ideal pavement; it is of durable material, is not very noisy, is easily cleaned, and is quite smooth, presenting small resistance to traction, and is not hard upon vehicles and horses. It is very close jointed, and the brick are nearly non-absorbent. When considerably worn, the upper edges of the brick are chipped off enlarging the interstices. But they are very shallow, and hold but little filth. Its cost is quite reasonable, being about 20 per cent. more than cedar blocks, $\frac{2}{3}$ the cost of Asphaltum, and a little more than one half the cost of stone blocks. The first pavement of this kind in this city, was laid in 1889, on Olive Street, north of Independence Avenue. It has been in service about four years, and is in good condition, and bids fair to do reasonable service, although the brick were not of the best quality, but the best available at that time. The second brick pavement was laid upon 18th. Street, and was a poor job, by reason of the poor quality of the brick. At that time there was no vitrified brick plant in or near the city. Since that time, a first-class vitrified brick plant has been established near the city, which turns out an excellent quality of vitrified brick, and several miles of brick pavement have been laid with good results. The brick seem to be

steadily gaining in good quality. They are now made quite uniform in quality and are exceedingly hard and non-absorbent, but seem to lack toughness. A small section of brick pavement was laid on Main Street at the intersection of 10th. Street, about two years ago, where the vehicular traffic is very great. It is now in good condition, and apparently good for two years more of the same traffic. Probably during the two years, in which it has been laid, it has carried as much traffic as any of our residence streets carry in ten years. If this be true, and it will last two years longer, under the same traffic, then it follows, that such a pavement will carry the traffic of a residence street for twenty years.

It was laid of selected brick, which doubtless were better than the average brick used in our streets, but with constant improvement in manipulation of the clay before burning, and improved kiln appliances, and methods of burning, we may expect a constant improvement in the brick until almost perfection is attained.

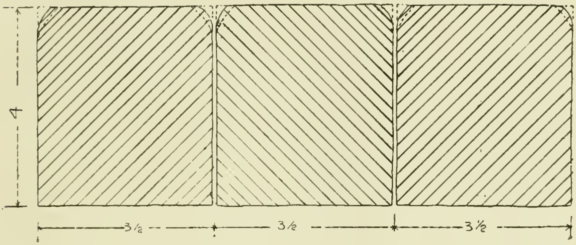
Lately some interesting experiments have been made in burning brick with electricity, and it is claimed for this method that every brick can be burned just alike, and that the exact amount of heat can be applied, for the exact length of time required, to get the best possible result, and thus, if the material is of the best, turn out a perfect quality of brick. If these expectations are realized, brick will become a favorite paving material for a certain class of streets.

It was natural that the experiments with brick should first be made with the usual size of building brick but now the experimental stage is passed, and the reputation of vitrified brick is well established, city authorities and brick manufacturers should look to the enlargement



of the size of the brick. The wearing surface should be enlarged at least 50 per cent. Then the pavement would present fewer joints, and a greater wearing surface for each brick. The first and main loss to the wearing surface of the brick is from the chipping off of the edges

of the brick, by the action of horses feet, upon the brick. In a few weeks, where the traffic is heavy, the loss is thus made of a quarter or three-eighths of an inch, on each edge of the brick, or a half to three-fourths of an inch in all, reducing the bearing surface of the brick, to one and one-half inches or less, which has to carry the whole burden of traffic, and this is gradually reduced and the wear is correspondingly increased. If the brick had a 3½ inch surface, when laid, then the loss of the half inch by chipping, would still leave a three inch wearing surface which would carry for years heavy traffic, and give very satis-



factory results all around. The brick need not cost any more per square yard, of area, because the depth of brick would not be increased. In addition to the increased size of the brick, the manufacturers should use every effort to increase the toughness of their output. Probably a slower cooling off would add something to their toughness. The present brick in use, seem as hard as granite, and as impervious, to water, but they lack toughness, and any money or time spent in experiments, to bring about an improvement in this respect, will be well spent. A tougher brick with a larger wearing surface, is the "way out" for vitrified brick.

If Colorado sand stone were laid in small blocks, of exactly the same size and shape of brick, I think the edges would chip off in the same way, and just as soon as they chip off the vitrified brick, and per contra, if vitrified brick were laid in as large blocks as the sand stone, they would last as long under the same traffic.

In all the prairie states, where neither timber nor rock for paving are at hand, and asphalt is too expensive, the young cities, when they arrive at the paving period, will doubtless pave with brick. One thing greatly in favor of brick is that it is a home production. Good brick material abounds almost everywhere in the West, and a brick pavement can be constructed without a dollar of money being sent abroad, except for the very small item of cement used in the concrete foundation, and even this item is eliminated, in small cities, by the use

of a layer of sand, and longitudinal layers of brick, for a foundation, in place of concrete; but this method cannot be recommended for Kansas City.

Brick paving can also be very easily repaired. The worn out brick being removed, and new ones put in their places, either in large or small areas.

Care should be taken that vitrified brick is not adopted upon streets carrying too heavy a traffic for the brick to withstand the heavy wear and tear of such traffic. If this be not done, streets will be paved with vitrified brick, which ought to be paved with other material, and failing to give the expected satisfaction to the property owners and the public, it will be declared unfit for paving purposes.

It would be a mistake to pave any street with brick, where the traffic is so great as to wear out the brick and to require paving within five years, from the time it was first laid. It would be much better not to lay it upon any street where it cannot be expected to last at least eight years. Every brick should pass the inspection of a brick expert, to insure that no inferior brick are used. The adverse criticisms of brick pavement no doubt come mainly from localities where they have experimented with poor brick, and the use of them upon streets carrying too heavy a traffic. Those engaged in the manufacture of vitrified paving brick should not fail to remember that their output is on trial, and that every street paved with good brick is a standing advertisement in its favor, and every street paved with poor brick is a lasting discredit.

ASPHALT.

This material is also a modern candidate for public favor, and, although it is but 24 years since the first asphalt pavement was laid in London, and 15 years since it was first laid in America in the City of Washington, it has already reached a wonderful and merited popularity in the commercial cities of Europe, as well as America, and is rapidly taking the place of other pavements.

It possesses every one of the merits of our ideal pavement. It is of durable material. It is free from noise, presents the least resistance possible to traction, is as smooth as a kitchen floor, and can easily be made perfectly clean, and although smooth, it has grit enough to prevent much slipping. It gives the least wear and tear to horses and vehicles. Having no joints nor interstices to fill up with filth, and being non-absorbent, it dries off very quickly, and compared with the cost of other pavements, its cost is reasonable, and besides, for the construction price the contractors give bond and guarantee, to keep it in perfect repair for five years, and at the end of that time to turn it over to the city in perfect condition.

We seem then to have found our ideal pavement, backed by a very

substantial and valuable guarantee of its lasting qualities but when we examine the situation, we find that even an ideal pavement is not suitable for all places and conditions in this city. Probably there is no other city in this country, that has so great a variety of surface, and so many steep and undulating grades as Kansas City. Some of our gradients are very steep, a large number being over 5 per cent. and some exceeding 10 per cent. Care should be taken not to lay it upon too steep grades. Some of our grades are too steep for asphalt, but the limit in this respect must be determined by experience. In some parts of the city the value of property is too low to stand the expense of a first-class pavement, and if paved at all, the cheapest pavement or macadam must be used.

In other parts there is a heavy freight traffic, and many take it for granted, that asphalt will not stand a traffic of this kind, that is, a traffic of heavy teams, hauling heavily loaded wagons, and that for this reason, asphalt will never supersede stone blocks, upon streets carrying a traffic of this character. Experience upon this point is much better than theory, so it is proper in this connection to present some facts, showing the estimation in which asphalt pavements are held where they have been longest in use.

In 1890, the Department of Public Works in New York City having seen the great success of asphalt pavements in Washington and Buffalo, and desiring to learn the best methods and materials in use in European cities, authorized its chief to send Asst. Engineer Charles H. Bull, to Europe to study the pavement question, and report his conclusions, and for your information, I quote from his interesting report, as follows:—

"I have spent a good deal of time in observing the effect of traffic over the various kinds of pavements, and in view of its recent use in New York, I particularly observed the asphalt pavement. In 1869, an experimental piece of asphalt pavement of 400 square yards area was laid in Threadneedle Street, London. That pavement, which of course has had many repairs since it was first laid, still remains, and is now in good condition. Soon afterwards the cleanliness, the absence of noise, and the comfort felt by the community generally from this asphalt pavement, enlisted the favorable opinion of the public, and lead to the paving of Cheapside and Poultry in 1870. These pavements remained in constant use for 19 years.

After Cheapside, many of the streets of the city were paved with asphalt, and gradually the stone pavements of the whole of the main thoroughfares, were replaced with either asphalt or wood, but mainly by asphalt.

The busiest and most constantly traveled streets in London, Paris and Berlin, are paved with asphalt, and the travel over them is continual and heavy. The life of asphalt pavement in London is considered

from 15 to 20 years. Threadneedle Street, Cheapside and Poultry, which were laid about 20 years ago, sustain an enormous vehicular traffic. The amount of travel over the streets of London may be appreciated when it is stated that 13,772 vehicles passed over the asphalt pavement on Cheapside, in 24 hours, February 21th. 1888, and on Mansion House Street, 23,332 vehicles in 24 hours, February 22nd. 1888."

These quotations are a sufficient vindication of the popularity of asphalt pavements in European cities. Mr. Waldo Adams, of the Adams Express Company, Boston, says:—"The Trinidad Asphalt pavement on Court Square, in Boston, has been in constant and very hard use, for eight years, and is in perfect condition to-day. We have over 300 Express offices in said Square, and it is constantly full of wagons with heavy loads."

Waldo Brothers of Boston say—"We have been located on Kilby Street and Water Street, since 1874. The Barber Asphalt pavement was put down on Water Street, Kilby Street, and Liberty Square in 1881. The streets named were always used for heavy teaming, and the pavement is as good as when first laid. It is the best pavement we have ever seen, as to its lasting qualities for heavy, or any kind of work."

Kilby Street is said to carry a traffic of 126 tons per square foot, every 24 hours.

From the foregoing quotations from disinterested men, (and many others of like character might be quoted,) we are led to the conclusion that asphalt pavements are very durable, and will successfully carry a heavy traffic.

The first asphalt pavement in Kansas City was laid upon Wyandotte Street between 6th. and 9th. streets in 1888. It was laid with a five year guaranty, which will expire in a few weeks. This street carries quite a large traffic, with heavy as well as light teams. The pavement now is in perfect condition, and appears to be in every respect, as good as when first laid. Whatever of repairs it has had, have generally been done quietly and silently in the night, so as to give no obstruction to the free use of the street during the day. Judging from this pavement and the five years service it has given, there seems to be no reason to doubt that with necessary repairs from time to time, its life would easily cover a period of twenty years.

The extraordinary adhesive qualities of asphalt, and its great tenacity of hold, has caused it to be used in a very unique and extraordinary way in many instances; that is in covering worn out stone pavements with a coating of asphalt, instead of taking up the stone blocks and putting in concrete foundations. The stone blocks after being hammered and pounded by teams and wagons for years, become very solid, and form a permanent and substantial foundation. All uneven and low places are leveled up with asphalt concrete, and the usual coating of

asphalt is spread, rolled and compacted upon this, and the pavement is then complete, its great adhesiveness holding it firmly to the stone block foundation.

Old macadam roadways have been successfully treated the same way. About half the asphalt laid in New York City, is laid upon old stone block pavements, and several macadam streets are covered with asphalt.

After what has been said about the durability and wearing qualities of asphalt, it would seem to be a safe proposition to lay it upon any street of proper gradient, no matter how great the traffic, provided that the Asphalt Paving Company will give the same guarantee for five or ten years, that they give for other streets.

Personally, I believe there is not a street in Kansas City, where the traffic is too great for an asphalt pavement to carry it successfully, and if the Barber Asphalt Co., with an experience of 6,000,000 square yards of asphalt pavement laid in this country, covering every kind of climate, for a period of 14 years, and which must know all the capabilities of their output much better than anyone else, and which is thoroughly responsible, proposed to lay an asphalt pavement at their current prices, in front of any of my property, carrying the heaviest traffic in thiscity, and would guarantee it for ten years, I certainly should give a willing consent.

Contracts for asphalt pavements should cover repairs for five years in the contract price for laying, and ten or fifteen years longer at a stipulated price per square yard, payable annually. Other kinds of pavements can be repaired by an ordinary street gang possessing reasonable skill, but an asphalt pavement can only be laid and repaired by experts who are thoroughly skilled in the manipulation and handling of asphalt, and hence the desirability and necessity even, of providing for repairs for a long term of years. With this stipulation we shall be sure of a complete and perfect pavement, without the trouble of looking after the repairs ourselves.

In London the Asphalt Paving Companies keep their pavements in repairs for 17 years, and in New York for 15 years. Conceding that asphalt is not suitable for very steep gradients, we then must decide what pavement is best for heavy grades, which carry a heavy traffic. Where it is not especially desirable to get rid of the noise nuisance, as upon our Bluff Street, from Union Avenue to 5th. St., where there are no residents to be annoyed, it may perhaps be best to lay stone blocks.

The present pavement of Colorado Sandstone, having been in use for 7 years, and already nearly worn out, demonstrates that Colorado Sandstone in not nearly equal to granite in wearing qualities, and hereafter, when it is decided to use stone blocks, granite should have the preference over sandstone.

Where it is especially desirable to get rid of noise, on steep gradients with heavy traffic, and there is doubt about the ability of vitrified brick to withstand the traffic, wooden blocks had better be selected, as they cost less than one-half the cost of stone blocks, and will last as long under heavy traffic as Colorado Sandstone and can be relaid for a little over one dollar per square yard.

I believe that a pavement of sawed white oak blocks, having no sap wood, and allowed to season a few weeks before laying, and laid in courses after the Nicholson plan, would give excellent satisfaction, with a smooth surface, and still giving a good foot-hold for horses feet. White oak is our most lasting timber, close grained, compact, and not easily broomed up or worn away, and I believe would make a very desirable pavement for especial cases, and an experiment on this line would be a wise and proper thing to do, and it is a matter of surprise that while we are convenient to an abundant supply of white oak—the most valuable and durable of all our woods—that no trial of it for pavements has been made, while cedar and cypress have been used so freely.

A white oak pavement could be laid on Bluff Street of sawed blocks, using the present concrete, for $1.25 per square yard laid in regular courses from curb to curb, with a space between each two courses of ⅜ or ½ inch, filled with coal tar and gravel, these spaces to give a foot-hold for horses. All the wood to be clear of sap, so as to prevent enlargement of interstices by early decay of the sap wood. The first cedar blocks laid on 6th. street, at and near Bluff Street, were relaid at the end of 6½ years. The present blocks have already lasted 4 years with 2½ more years service in prospect. Then 6½ years is a fair estimate of the life of cedar blocks on this street, carrying the heaviest traffic of any street in the city, and Colorado sandstone wearing out under the same traffic in seven years, we find that even cedar blocks pretty near equal Colorado sandstone in wear under heavy traffic. I have no doubt that white oak blocks will last, under the same traffic, a year and a half longer than cedar blocks, or at least eight years, and would expect them to last ten years; but even at eight years service, here is a gain of a year in life over Colorodo sandstone at a considerably reduced expense, as well as a greatly reduced noise and wear and tear to horses and vehicles, and a reduction in resistance to traction.

When the present stone block pavement on Bluff Street is overhauled—which it soon must be,—it would be a wise and proper thing to put in at least four or five hundred square yards of white oak pavement, and give it a fair trial.

The cost of asphalt paving in this city must be considered as reasonable, when compared with its cost in other and Eastern cities, where competition is encountered. In Buffalo, N. Y., the champion of as-

phalt pavements, there are three competing companies; the Barber Asphalt Co., the Buffalo Paving Co., and the German Rock Asphalt Co., all in competition. The two last named companies use pulverized bituminous asphalt rock, which is generally used in European cities.

Contracts for paving in Buffalo, made in 1892, laid over for completion in 1893, equal 411,240 square yards, and cover 24.92 miles of streets, all of which, except 0.85 miles are of asphalt, and the average cost of the asphalt pavement is $3.10 per square yard.

The consulting engineer of the Commissioner of Public Works of New York City, in his annual report for 1892 says of asphalt pavement:—"During the past four years I have carefully observed the traffic on the asphalt pavements, with the view of determining if there was any difference in the slipperiness in the two kinds in use, one composed of Trinidad Asphalt and sand, and the other the imported natural rock asphalt. It was particularly noticed that horses slipped and fell more frequently on pavements of the natural rock asphalt than on pavements of Trinidad asphalt. I am satisfied that it will be for the City's interest to discontinue the use of imported natural rock asphalt in pavements, and also discontinue the use of the "overflow" asphalt from the Island of Trinidad, and use only that taken directly from the Pitch Lake."

From this it seems that we are fortunate that our asphalt pavements are laid from the material from the Pitch Lake, and also that the price per yard is lower than in cities where they have competing asphalt companies.

In New York City, where they have competing asphalt paving companies, and Trinidad asphalt comes in competition with bituminous or asphalt rock, the cost of asphalt pavement in 1890 was $3 10 per square yard, the same as the price paid in Buffalo. As this is 30 cents per square yard more than we pay for Trinidad asphalt pavement here, it is not likely that we will ever get it any cheaper, and compared with other cities and other pavements, the price is reasonable, although of course we will welcome competition in this, as in everything else.

Buffalo had 125.67 miles of asphalt pavement up to January 1st, 1893. Contracts for this year for asphalt pavement cover 24.07 miles, so that at the end of this year, it will have almost 150 miles of this smooth and noiseless pavement, covering 2,528,595 square yards, and costing about $8,000,000, all laid during the last eleven years. This record of a city with only 255,000 population in 1890, shows the great enterprise of its people, and is the highest possible commendation of asphalt pavement, after giving it a thorough trial for eleven years.

Further statistics upon this point are unnecessary.

MATERIALS.

After having selected the kind of pavement we are to use, we must

next look to the materials of which it is to be constructed, for upon the kind of materials, and the workmanship and skill used in its construction, depends the value of the completed pavement; and if poor materials and unskillful workmanship enter into the construction, the pavement will be unsatisfactory, and bring it, and its kind, into discredit.

All pavements are composed of two distinct parts—the foundation and wearing surface. In former times, most pavements were laid upon a foundation of sand, gravel or broken stone, which were uncertain and liable to settle, and throw the pavement out of surface. Modern methods require a foundation of cement concrete. It should never be less than 6 inches thick, and great care should be used that all the work connected with it is well done, and all the best of its kind.

The earth after being excavated to its proper depth, should be thoroughly rolled with a heavy roller, before receiving the concrete, which in turn should be thoroughly rolled and compacted and allowed to become well set before the wearing surface is put in place. Great care should be taken that the surface of the concrete has a smooth surface, exactly parallel with the contour of the wearing surface, so that when completed, the pavement will have a perfectly smooth uniform surface and will stay there, and cannot settle out of surface at any point.

Thereafter, any irregularities in the wearing surface, must come from wearing away the surface itself, and not from settling out of shape. To insure exactness of surface, a templet should be used, reaching from center of street to curb line, and the concrete brought exactly to this templet. All work and materials should be constantly under the eye of a competent inspector, who has got the nerve to inspect. The care with which the Barber Asphalt Co., does all its work, secures a perfect wearing surface which never settles out of shape but always maintains a perfect contour. Other paving contractors will make no mistake in following so good an example.

PROTECTION.

The city having secured the paving of its streets entirely at the expense of the abutting lot owners, and being itself exempt by charter from the payment of a dollar, even for the intersection of streets. is in duty bound to give the utmost protection to the lot owners, who have paid the bills, by preventing any undue or reckless damage and wear and tear to the pavements, and thereby precipitate the time when the lot owners will be called upon to foot the bills for repaving the streets.

This the city can do by legislation, and requiring its legislative enactments to be strictly enforced.

The two great destructive agents, which wear out and destroy our pavements—whether they be good or bad—are the vehicles which pass over them and the feet of the animals which haul them. With light horses and buggies, this wear is not excessive, but with teams hauling

heavy loads (many of the wagons with their loads weighing three or four tons,) the strain upon the pavements is very great. Take a load with the wagon weighing 6000 lbs., and the wagon with a 2″ tire, when it is new and has a full width bearing. The load rests upon the pavement upon four points, each not exceeding more than four square inches, or 16 square inches in all. Each square inch then sustains 375 lbs., of the weight, equal to 27 tons per square foot, or ten times the pressure upon foundations of our tallest buildings.

This is a startling statement, but it is true. This is the pressure at the point of contact of the wheel with the pavement and does no harm elsewhere, but here—when the vehicle is moving forward over a rough pavement, it is a very destructive force, and will, after a while, wear away the hardest granite.

Another and still greater destructive force, is the feet of heavy draft animals. Take for instance a draft horse weighing 1500 lbs. At a standstill his weight rests upon three corks upon each shoe. These corks when new have an average bearing surface of about ½ square inch to each cork, or 1½ square inches to each foot, or an aggregate of six square inches for the four feet. The weight of the horse (1500 lbs.,) upon six square inches equals a pressure of 250 lbs., to the square inch, or at the rate of 18 tons per square foot.

This is when the horse is at rest. The moment you put him in motion, the case is greatly intensified, because the weight instead of being steadily upon four feet, is taken upon two feet alternately as the horse moves forward. Still worse, at every step the foot comes down with sledge-hammer force, and the heavier the load, the greater the muscular action of the horse, and the greater the force of the blow.

Watch a team loaded to the limit of its strength, hauling its load up a grade, and you will see that the full force of the blow comes first upon the toe corks of both the fore and hind feet, and so strongly is this the case, that they seem almost to dig into the pavement for a foot-hold.

These destructive forces should be regulated by law, so as to protect our pavements as much as possible. Wagon tires should be regulated in width. Any wagon carrying a ton, net weight, should have three inch tires. The wagon trucks carrying heavy machinery, iron, etc., weighing five or six tons, should have 6 inch tires, and intermediate loads have tires of intermediate widths accordingly.

In London and Paris and Berlin, shoe corks are prohibited by law, and all horses are smooth shod. This hardly would be admissible on our heavy grades, but half corks should be sufficient. Now every smith shoes to suit himself, and some draft animals when newly shod, walk upon three corks on each shoe so long that the animal seems almost walking on stilts.

The sooner these matters are regulated by law the better for our pavements. If our Board of Public Works would take this matter in hand, and bring about this much needed reform, the lot owners who pay the bills, would "rise up and call them blessed."

COMPARATIVE COST.

The average first cost of pavements in this city, laid upon a foundation of six inches of hydraulic cement concrete, is:—

for Colorado sandstone and granite blocks. about........ $3.25
" Vitrified brick.................................. $1.80
" Cedar blocks..................................... $1.55
" Asphalt.. $2.80

per square yard. These are prices paid in special tax bills, and are probably 10 or 15 per cent. higher than they would be if paid for in cash.

The life of each, before requiring a new wearing surface, under the conditions of climate, and the amount of traffic which they carry in this city, can be closely approximated from our experience with all, except vitrified brick, which has only come into use during the last four years.

I estimate the life of the different kinds as follows:—

Colorado sandstone................ 7 years.
Granite............................ 10 "
Vitrified brick.................... 10 "
Cedar Blocks....................... 8 "
Asphalt (with repairs)............. 20 "

Of cousre there may be cases, where with light traffic, and but little of it, each kind of pavement would last much longer, except cedar block, which I think decay quite as soon with but little traffic, as with a great deal. What we seek is the average life of each kind of pavement, according to the traffic it is likely to have to carry.

Taking first cost and life of pavements into consideration, without including any interest on first cost, and for a long term of years we can estimate pretty closely, the cost of each kind per annum, as follows:—

Kind of Pavement.	First cost.	Term of years.	When relaid.	Cost relaying.	Total cost.	Average cost per yard per year.
Colorado sandstone..	$3.25	14	End of 7 years.	$1.20	$4.45	31¾ cts.
Granite..................	3.25	20	End of 10 years.	1.20	4.45	22¼ cts.
Vitrified brick...........	1.80	20	End of 10 years.	1.40	3.29	16 cts.
Cedar blocks.............	1.55	16	End of 8 years.	1.15	2.70	17 cts.
Asphalt with 5 years' Guarantee...........	2.80	20	Repairs 8 cents per annum for 15 years.	1.20	4.00	20 cts.

From this statement it appears that cedar blocks, although the first cost is 20 per cent. cheaper than vitrified brick, costs one cent per square yard per annum more than vitrified brick for a long time term of years, and when this becomes understood, cedar blocks, except for especial cases, upon grades as heretofore mentioned, will no longer be laid in this city, although they were a very important factor in our pavements before the advent of vitrified brick.

In the same manner, with Colorado sandstone at 31¾ cents, and granite at 22¼ cents per square yard per annum, the sandstone will give place to granite in places, where for special reasons it is desirable to lay a stone block pavement.

The low price given for relaying stone block pavement is based upon the idea that about half the stone blocks in a pavement, can be laid upside down: and used the second time, while the other half would be new stone from the quarries.

REPAIRING AND CLEANING.

Too little attention is paid to cleaning and repairing pavements in this country. In European cities they are repaired promptly and as soon as any deficiencies are discovered. In this country, we are apt to let them get into a dilapidated condition and repair them scarcely at all, and as a consequence, after the period of great wear and depreciation is reached, we go on from bad to worse, until many of our streets are allowed to get into a very dilapidated condition. Doubtless this condition of things will be remedied as we progress.

After obtaining good pavements, they should be kept clean. They should be swept three times per week, and the principal streets every night. The slow, cumbersome and expensive shovel and hoe should be dispensed with, and give place to modern street sweeping machines. The street cleaning and sprinkling should be done by contract, and be paid for by the city.

The city should also pay for all repairs to the pavements. The lot owners having paid for paving and repaving the streets, the public at large having the use of the streets, and doing all the wear and tear, and all the littering of the streets, with droppings of all kinds, should pay for cleaning, sprinkling and repairs, and not load all this extra expense back upon the helpless lot owners.

Thousands of lot owners who pay for paving the streets, and keeping them in order, do not own a team or buggy, and never expect to, and do no travelling whatever upon the streets of the city. To compel them to bear the whole burden of grading, paving, repaving, repairing, cleaning and sprinkling streets which they never use, is very unjust.

To allow all kinds of wagons, big and little, heavy and light, corporate and private, whose owners perhaps do not pay a dollar toward

paving and maintaining the streets, and keeping them clean—but who litter them up and wear them out, to escape without the payment of any street tax whatever, is so manifestly unjust, that it is surprising that such a system ever can be maintained.

SIDEWALKS AND CURBING.

Although sidewalks and curbing are a little beyond the scope of this paper, still as they form a part of a completed street, it may be proper to say that as natural stone and wood will give place to artificially prepared asphalt and vitrified brick, so natural stone for sidewalks and curbing, will give place to artificial stone, in the interests of beauty and uniformity, as well as durability and economy.

Artificial stone composed of crushed granite, or sharp sand and gravel, mixed in proper proportions with the best Portland cement, will outlast the best natural stone, with the possible exception of granite, and can be furnished in place at much less cost than natural stone, which will deteriorate under long exposure to the elements, while artificial stone if properly and faithfully manufactured, with the best material, will endure for generations. It will stand a greater amount of foot-wear from pedestrians than any stone other than granite. What asphalt is to street paving, artificial stone will be to sidewalks and curbing. Curbing can be constructed of the same materials, fitted, moulded and completed on the ground and in place, and when the time shall come to replace our dilapidated natural stone curbing, with new material, artificial stone should replace them, and all new curbing should be built of this valuable material. A ride through such delightful young cities as Los Angeles, and Minneapolis, where neat, clean and perfectly constructed curbing abounds, with block after block of artificial stone sidewalks, all of uniform width, color and construction, will convince anyone, however skeptical, that artificial stone is the coming material for sidewalks and curbing, and to have a handsome street the sidewalks must be of uniform width, kind and color. A street however well and carefully paved cannot be a handsome street without corresponding well constructed sidewalks and curbs.

American cities have made great strides in street paving the last 20 years. Forty years ago the cobble stone pavement and the macadam road held almost undisputed sway in this country, and it is only 44 years since stone blocks superseded cobble stones on Broadway, New York, probably the most important thoroughfare in America.

Many of our cities now having from 100,000 to 200,000 population, like Kansas City, Denver, Omaha, St. Paul & Minneapolis then had no existence even as villages. It is not surprising that having so much to do, in the up building of our cities, requiring the expenditure of such vast sums of money—both for public and private purposes—we have been behind the old cities of Europe in paving our streets; but

with the rapid increase in population and wealth, has come the demand for better pavements, and fortunately we are not obliged to copy from another Continent, for with the demand for better pavements and more of them, has come better and more desirable paving materials, and now American Cities are rapidly coming to the front in street pavements as they already are in almost everything else.

The city of Buffalo began to emerge from the cobblestone era, only a few years ago, and now with its 150 miles of asphalt paved streets, covering more than 2,500,000 square yards of surface, it is, with the possible exception of Berlin, the best paved city in the world.

Washington comes next with nearly a million square yards of asphalt pavement, and many other cities large and small, are rapidly following the example of these two notable champions of good pavements.

CONCLUSIONS.

If our argument is based on facts, and our analysis is correct, then we must come to the following conclusions:—

First. That no pavement however perfect in itself, is or can be suitable to all conditions of grades, value of property, and amount of traffic in this, or any other city.

Second. That asphalt nearly, or quite possesses all the merits and fills all the requirements of an ideal or model pavement, and will be adopted on all streets where the grades are not too steep, and the property is of high value, with few exceptions on account of extremely heavy traffic.

Third. That vitrified brick takes second place, and when the various processes of manufacture are perfected, and the wearing surface of each brick is increased about 50 per cent. it will become a favorite pavement for the cheaper class of streets, as well as on grades too steep for asphalt.

Fourth. That stone block pavement has so many demerits, that it will gradually give place to asphalt or vitrified brick, except in particular and exceptional cases.

Fifth. That while cedar block pavement has heretofore done us excellent survice, as a pioneer pavement, by reason of the slight difference in cost, it will generally be superceded by vitrified brick, on streets requiring a pavement cheaper than asphalt.

Sixth. That after requiring the lot owners to pave the streets, it is the duty of the city to clean, sprinkle and repair them at public expense, and by legislation, regulate the width of wagon tires, and the shoeing of horses, in such manner as to give the least wear to pavements that is practicable, and see that the spaces between the rails and tracks of our street car lines, are put and kept in as good condition as the rest of the streets.

No doubt that with the enterprise that dominates all American affairs, and the public spirit and emulation that is abroad in all our land, American cities in the next two decades, from being the worst paved (as they were two decades ago,) will become the best paved cities in the world.

ENGINEERING THE ESTABLISHMENT OF COMPETITIVE ENTERPRISES.

By Thomas D. West, Member the Civil Engineers Club of Cleveland.

[Read September 12, 1893.]

In days of sharp competition, the starting of new enterprises soon places upon the shoulders of its managers and investors a weight they had not figured on carrying, and all sentimental ideas of self importance and there is "millions in it" vanish long before dividends are declared.

Could the struggles of late enterprises to get a foothold be fully outlined, we could not fail but to have volume after volume giving recitals of trials, that could the principals in them have foreseen what they had to go through and the chances to be taken ere they could establish a paying business, there would have been much hesitancy before starting in and a great probability of their not having done so.

The writer having fought through two such undertakings within the past five years, the first being lost by fire, should be in a position to know from experience some of the difficulties attending the establishment of a business open to free competition, an element most all new enterprises have to figure on combatting.

PROCURING PROFICIENT EMPLOYEES.

Of the many struggles to be met and mastered there is none more serious than that of getting a works filled with competent faithful employees having qualifications such as are necessary to fill the many different characteristic lines of work called for in their business.

I know there are those which would not believe it but nevertheless such is true; there are industries which it may take from one to three years to procure the character of employees they would like to see filling all posts of duty, and one factor most all new enterprises should specially figure on at the start is that of not being compelled to rush out work to the full capacity of the plant.

GO SLOW THE FIRST YEAR.

The endeavor to do this will often entail serious loss financially. There are few whose character of manufacture will admit of such pro_

ceedings without loss, but with most all it is much the better plan to go easy for the first year and be under as few obligations as possible in matters of manufacturing their product.

In first starting business the quality and quantity of an employee's daily output is to be considered and a new firm will by having new appliances etc., have their own customs and standards they will desire to see adopted and achieved, and no matter if the mechanic or employee did do the same character of work in his last place, their standard is not yours and you want the benefit of modern arrangement and tools and the work done to your ideas.

If your plant is rushed your men will know it and in nine cases out of ten you will find yourself placed in the position to shut up shop or let the employees establish their own notions of the customs and standards to be adopted.

No one but an experienced manager knows how difficult and expensive it is to undertake to change the customs and standards in a workshop after they are once established.

If in first starting up, a firm could be assured of filling all its positions with men having the character and qualifications they would like them to have, and not before they can procure one such, have to discharge in some cases a dozen, business could be figured differently and the rushing of the plant to its full capacity, turning out the quality and quantity desired profitably, could be much more satisfactorily relied upon.

Taking the employee's side of the subject, it is also better for them that the starting off of a new plant should go slow, for it gives all more room to work, a better chance for the overseer to assist them in systemizing and becoming accustomed to their labors, and should the employee at first not manifest the ability required, business not being rushing, the overseer can permit the man hanging on a little longer to see if he can make any success of him and often eventually thereby making a good reliable man that can stay as long as he may desire, otherwise he might be walking the streets looking for work.

ENDANGERING LIFE AND BREAKING MACHINERY.

A factor to also be considered by the employer and the employee in starting a new plant is the much less risk taken of persons being injured where there is much new machinery with green hands to run it.

It is much better for the overseer to have ample time to watch and educate employees in the use of tools and machinery than have them all crowded together with a, "go as you can" principle, injuring themselves and breaking machinery.

TESTING NEW MACHINERY.

Another good reason why it is advisable for new firms to figure on going slow the first year, is to test its machinery. The plant is yet to

be built that for the first year did not discover many weak points in its appliances and machinery that required shut downs and time to strengthen and repair, and if rushed with work things will often be found to go wrong that would not have given any trouble could there only have been time spared to humor and nurse them, for new machinery often requires such treatment in order to have it run and act well just as much as a sick child.

FINANCIAL TROUBLES.

In nine cases out of ten a plant will be more sure of making money by going slow the first year than by attempting to drive the plant to its utmost capacity and, it is pretty sure to be the case that more money is laid out to put up buildings and place machinery ready to start than was figured on, and the establishment often finds itself left with a very small working capital; if with such it is attempted to rush business the first year, the chances are very favorable for the plant sinking or getting in a hole it will require several years of profitable work to get it out of, if at all, for when financial matters start going down hill they often go as if on a greased plank. In business matters the margin for profit these days is very small.

A firm cannot survive many blunders and the attempt to rush business the first year is generally to try a risk, "Be sure you are right then go ahead."

DISCUSSION.

The Chair: The subject that Mr. West has brought before you is now open for discussion. It is one we have often discussed in regard to the idea that people start in, thinking there are "millions in it," and then find out there wasn't anything.

Mr. L. Herman: Starting new enterprises is a science by itself. The mistake most often made is in the location selected for a new factory. Very seldom do we find a factory put where the transportation for raw material and for the finished product, and the power and fuel are in the most favorable condition to be obtained. I have seen many plants doomed to go to wreck and ruin on this one account.

Another mistake very often made is in putting the plant where the labor is not obtainable in such quantities and kind as is necessary, otherwise, I cannot but admire Mr. West's paper.

Mr. West: I would like to state that Mr. Herman's remarks touch on a subject upon which I have another article. This is one of a series of articles which I am writing for a work to be entitled. "The management of men in manufacturing industries." In that article, I touch on the matter of location; this is a very important matter, as Mr. Herman suggests. There is another very important element in locating that is generally overlooked, and that is the matter of knowing the

kind of help you can get in that locality. We find in small towns that the workmen are characteristic in their special way; they have been drilled in a certain kind of work, and if your work is different from that, it will cost considerable money to establish yourself. I have had this experience recently upon going into a village where the majority of laborers were blast furnace men. Our business required men who could keep steady at work, and these men had been used to the principle of working one hour and sitting down two. We found it was very difficult to get men who could carry out our line of work. This is a point in which you cannot be too careful in investigating the field where you intend to get your supply.

MR. JOHN WALKER: I heartily endorse the paper that has been read, having passed through similiar experiences. I recognize that Mr. West has been through the mill not only by his paper, but by the experience he has had in the city. So far as the proper location of a manufacturing plant is concerned, I may say that persons should be very careful indeed in weighing all the particulars. It is not only a question of getting a switch to the works, but it is a question of the city. Before we located in Cleveland, I visited seven states, and spent fully half a year making a selection. I knew Cleveland was the place I wanted to go to, and finally found a place suitable, as I thought, for the works. It is very easy to understand that the principal things we require are the raw material, and the help to transform that into salable products. We have a remarkable incident here in Cleveland. Warner and Swasey, when they were in Chicago, could not get the men they wanted. The men would come into the works on Monday, and look at one another and say, "Well boys, shall we go to work today?" The firm had to look for a place where men had more respect for their employers, for themselves, and for labor.

So far as the establishing of a plant and making it a paying success is concerned, it requires a man of careful habits. He must have some knowledge of all the material he has to handle, and of the character of the men who are to help him; and he must have a careful man under him in every department. The business must be thoroughly managed. In making a competitive test with different men in different lines at one time, I found as high as thirty per cent. difference in a day's work, when the man himself was almost unconscious that he had done it. It pays to have the men understand that they are appreciated; I have never found any advantage in driving men; by stroking them a little bit, we get along better.

Our manufacturing industries in this country are, I think, largely coming to specialties. We all understand that we cannot produce as much by a mixed business. We may have a variety of business, but it is only when each of the branches is thoroughly con-

ducted as a business by itself that you are successful. We have a wonderful illustration in this respect in where they had work of all kinds from a monkey-wrench to a fancy engine and traveling crane. Hence it would be wrong to say that a variety of works cannot be made a success; but in general it is necessary that the works be essentially divided and distinct, as though they were separate manufactories. I believe that the more successful and paying concerns to-day are those that stick strictly to one kind of business.

George H. Corliss, in his last days, conceived the idea of getting standards of all his engines so he could lay parts of his engine away and know they would fit when they came together. He had the system so thoroughly grafted in his mind that it was essential to manufacture down to the very last point of economy, and stick to that one thing and not change. The last remark in the paper, "Be sure you are right and then go ahead," is a very good thing, and Geo. H. Corliss usually was correct, but on a few things he was not. I am sorry to say some of his designs are somewhat questionable, and the work of to-day has proved that certain things were not as perfect as they might have been. I believe he was conscientious in what he thought, but he had made up his mind that so far as he was concerned that was the shape and kind to produce, and hence his idea to perfect his shop on that line. I am sorry to say he did not live to complete it, or we might have seen one of the most thorough and systematic engineering machine shops ever brought together in the world.

Mr. J. L. Gobeille: To be a successful manager of a manufacturing business is to succeed. That is all that is necessary. No matter how big a fool a man is, if he makes a success of a manufacturing business, his fortune is made, and he is called a pretty smart kind of a fellow. On the other hand, some men deceive themselves as to the cause of their success. They think a certain way of wearing their clothes or something of that kind helps to success. If a man starts to succeed, he succeeds by looking after things personally. Then he has to *make* his men, he cannot hire them. I run men on the gang system. I pay the gang foreman 75 cents more a day than the rest of the gang, and have from seven to nine in the gang. When the gang foreman leaves or is discharged, another man from that gang is appointed as foreman, and that man has the same wages as the former foreman, no matter what he has been getting. He has the selection of the men to fill his place; he puts in his brother-in-law or somebody else if he wants to. That keeps all these men working pretty hard for the place at the head of the gang. Another thing that militates against success in the manufacturing business during the first and second year is that people go too far in competition. They think more of beating the other fellow out of a job than of getting it themselves. For my part I would not go

across the street to fight a competitor. I would rather get business for my own concern than spend my time getting business away from some other fellow. I consider that an element of success in a new business. Success, especially if you are a stranger, is to have good credit with people and companies who have money to lend. That has been exemplified in the past month or two.

When I came to this city eleven years ago, I had seventeen hundred dollars. I inquired for the best bank, and I told them I had been foreman at such a place, and that I had saved this money. That bank has taken care of me ever since. Sometimes they have had a pretty hard job of it and have debated some as to whether they would do it or not.

MR. E. P. ROBERTS: With reference to people not always paying special attention, I suppose members of a corporation do not take part actively in the management of a concern, in the receiving of raw material, and the handling of men. I think the matter of receiving raw material and shipping goods is one that deserves great consideration. In the matter of employees, a manufacturing concern of which I was manager moved their works from one portion of the town to another. I said it would not do; that we could not get our employees over there; and we did have to start afresh with nine-tenths of them. The corporation thought that that would make no difference, because they were cheap hands, mostly girls. But they found out it did make a difference in the dividends for a year or two. Even if they were cheap hands, most of them had to be trained. I mention this as a little fact on the same line.

THE PROBLEMS TO BE SOLVED IN THE TREATMENT OF HYDE PARK SEWAGE.

BY F. W. TUTTLE, MEMBER, ENGINEERS' CLUB OF KANSAS CITY.

[Read June 12, 1893.]

Our subject for to-night, the discussion of which you have requested me to open, is worthy of our consideration. Next in importance to an abundant supply of wholesome water is the prompt removal from our homes of those household wastes, which, if allowed to accumulate, will injuriously affect our health and comfort.

Hyde Park is within the corporate limits of the City of Westport and our conclusions will apply to that portion of Westport lying within the water shed of Brush Creek and extending from the State Line to Cherry Street. This portion of the City is bounded on the north by Springfield Avenue from Cherry Street to Warwick Boulevard and

west of Warwick by an irregular line following the summit which crosses South Main Street at the Grand Boulevard follows Grand Boulevard to Washington Street and extends thence south on Washington Street to Thirty-seventh Street; thence west on Thirty-seventh Street to Belleview Avenue; thence south on Belleview Avenue to Thirty-ninth Street; thence west on Thirty-ninth Street to Wyoming Street and thence south-west crossing the State Line at Davidson Avenue. It is bounded on the south by Westport Avenue, west of Holly Street and by Forty-seventh Street from Holly Street to Cherry Street.

The area of this district is 1400 acres. The elevation of the northern summit is 280 feet above the Kansas City datum at Springfield and Warwick Avenues and 250 feet at the State Line. Its minimum elevation is 240 feet at Thirty-ninth and Elizabeth Streets. The elevation of the bed of Brush Creek is 90 feet at South Main Street. The general slope to the south is broken by Harris Branch Valley which heads near Thirty-third and Oak Streets and extends south along and near Oak Street to Thirty-ninth Street and thence south-east, crossing Forty-seventh Street just west of Troost Avenue; also by Mill Branch Valley, which heads just north of Westport Avenue near Mill Street and extends in a south-easterly direction to a junction with Brush Creek near Main Street.

The population of Westport numbers about 4,800. It is almost exclusively a residence district and many of the better homes in the vicinity of Kansas City are located here. Its assessed valuation is:

Real Estate..........................	$1,504,708.00
Personal Property.....................	230,810.00
Total...............	$1,735,518.00

Under the liberal provisions of the state law concerning cities of the fourth class, much public work has been done by this city during the last two years. The following figures have been furnished me by Mr. Stalnaker, City Engineer:

75,622 lineal feet of street grading, costing	$85,247.78
91,018 lineal feet of curbing, costing.......	48,656 29
47,792 lineal feet of side-walks, costing....	16,573.74
52,696 lineal feet of street paving, costing	154,341.04
Total................	$304,818.85

The cost of maintaining the Engineering Department which has handled this work has been $6,800.00, or only about 2 per cent. of the value of the improvements, which is certainly a very favorable showing. Westport's water supply is furnished by the National Water Works Company who have within the city limits seven miles of street mains, fifty-three hydrants and 274 house services.

There has heretofore been no law under which Westport could construct sewers, and for this reason, none have been built except by private parties. There is a five foot brick sewer in and near Oak Street from Thirty-fifth Street to Thirty-eighth Street and perhaps half a dozen lines of pipe sewer, aggregating not more than 3,000 feet which empty into Harris Branch.

Sewerage for Westport and for all cities in the State of Missouri having more than 2,000 and less than 30,000 inhabitants, and for cities of the third and fourth classes, is provided for by a recent Act of the State Legislature.

To enable any such city to avail itself of the provisions of this act, it is necessary that two-thirds of the qualified voters of said city, voting at an election held for the purpose, shall favor its adoption.

Such city must then be divided by ordinance into two or more districts and may, upon the petition of the property owners representing a majority of front feet of private property in a district, or whenever the municipal authorities deem it necessary, acquire by purchase or condemnation, both within and beyond the territorial boundaries of said city the right of way for sewers and the use of natural water courses for public drainage or sewer purposes. They may construct sewers with inlets, laterals, branches and appurtenances either wholly within a sewer district or partly within two or more districts or partly in one or more districts and partly beyond the territorial limits of said city, as determined by the ordinance.

The cost of acquiring the right of way and of the use of a natural water course and of sewers and their appurtenances shall be paid for in special tax bills against the land, exclusive of streets and alleys embraced within the sewer district or districts in or for which the sewer or any part thereof may be constructed.

Westport has not yet decided to avail itself of the provisions of this act.

Of the different methods of sewage removal, I think, for Westport, we need only consider water carriage. This is the method almost universally adopted in this country and the only practicable one where the water closet is in general use. If we are agreed upon this we will remove the household wastes through sewers, having a continuous grade to the outlet, with a fall sufficient to make them self-cleansing, of a size neither too small nor too large, thoroughly ventilated and impervious.

We will also agree, I think, that we cannot discharge the crude sewage of Westport into Brush Creek without offense. We are prevented from doing this both by sanitary and legal considerations. This stream has not at all times a sufficient volume to dilute the sewage beyond the power to do harm. The amount of crude sewage which

can properly be turned into a natural water course varies somewhat with the character and velocity of the stream. If the ratio is greater than one to three hundred, the pollution will be probably sufficient to render the water unsafe for ordinary use for some distance below the point of discharge of the sewage.

If we are to use Brush Creek as our out-fall we must therefore purify the sewage before we admit it to the stream. The alternative is to convey it to the Missouri River, a stream of sufficient volume to digest the wastes of many cities. In either case we must exclude the storm water from our sewers; that is, we must adopt a separate system.

We are all familiar with the claims of the advocates of this plan. They are briefly:

First. A cost of about one-fifth that of a combined system to serve the same territory.

Second. The advantage of thoroughly cleansing the streets and gutters by keeping the storm water on the surface as long as possible without harm.

Third. The fact that large sewers with a rough interior surface become very foul and unsanitary during dry weather from the decomposition of particles of sewage, which, during storms, adhere to their sides above the height of ordinary flow.

Fourth. The fact that it is practicably impossible during storms to handle by any method of purification the discharge from sewers into which surface water is admitted.

In the case of Westport, Brush Creek will always afford a satisfactory outlet for storm water, even if it should in the future be found desirable to convey it to the stream below the surface of the streets.

An essential feature of the separate system is the flush tank. During the summer months rains are so infrequent that, even if the roof water were admitted, it would be insufficient to keep the sewers in a sanitary condition. The only practical way in which this can be done is by the use of a flush tank at the head of each lateral. Of these there are many forms. The better tanks in general use are operated by automatic siphons having no moving parts, or by gravity. The siphon tanks discharge from 300 to 500 gallons once or twice in 24 hours and the gravity tanks a smaller amount at shorter intervals. The cost of the water used is from $10 to $30 per year each.

Whether we decide to discharge crude sewage into the Missouri River or to purify it to such an extent that we can properly admit it to Brush Creek, we must in either case collect it at some one point. The natural point for such a purpose appears to be near the intersection of Forty-seventh and Campbell Streets. Here the main sewer from Mill Branch valley can be led to intersect the main in the valley of Harris

Branch. All of the city, except the south-west portion, which is at present very sparsely settled is tributary to these two mains.

It is hardly within the province of this paper to attempt to indicate the definite location of these mains or of their connecting laterals. This cannot be done intelligently until after complete surveys have been made and the question carefully studied. The requirements are a well considered general plan in advance of any construction.

Having then arrived at Forty-seventh and Campbell Streets we come upon the question which we are here to consider.

Let us look first at the various methods of local treatment. The impurities with which we have to deal constitute less than $^2/_{10}$ of 1 per cent. of the output of the sewer. The inorganic portion of these impurities is harmless from a sanitary standpoint. When a nuisance is produced by sewage, the direct cause is usually the development of organisms fed by the organic matter. The removal of this organic matter is what we wish to effect. We may accomplish this to a greater or less extent by sedimentation, mechanical filtration, chemicals, electricity, broad irrigation or intermittent filtration or by some combination of these methods.

The history of sewage purification in England dates back about fifty years. Mechanical filtration was the method first employed: and planks perforated with holes, coarse iron slag, charcoal, coal ashes, gravel and sand were the filters used. It was found possible by this means to remove most of the solid matter in suspension, but not the matter in solution. Mechanical filtration and sedimentation are not effective where an effluent of any great degree of purity is essential, except as a first step to be supplemented by some other process.

The chemicals most commonly used in sewage purification are lime, copperas, ferric salts and alum. The quantity required costs from thirty to fifty cents per inhabitant per year. From one-half to two-thirds of the organic matter of sewage can be removed by chemical precipitation. The process involves settling or precipitation tanks, which are usually constructed in duplicate; one set being cleaned while the other is in use. On the addition of the chemicals a jelly is formed which rapidly finds its way to the bottom, carrying the impurities with it. The water is then drawn off from the surface and conveyed to the nearest stream.

The first practical attempt at sewage purification by electricity was made in April, 1889, by Mr. William Webster of London. The quantity dealt with was 12,000 gallons per hour. The sewage was passed in a thin layer through channels and was subjected to the electrolytic action of positive and negative electrodes, made of cast iron and having a very extended surface. The result was a rapid precipitation of the organic matter in suspension, the oxidation of the organic

matter in solution and the decomposition of the inorganic salts. The consumption of the iron was not rapid. The effluent was clear and odorless. The mechanical power required was about 8 H. P. per 10,000 people. The cost was $3.12 per 1,000,000 of gallons of sewage treated.

In the processes which have been mentioned the disposal of the solid portion or sludge is the final consideration. It contains about 90 per cent. of water, a large portion of which must be removed before the material can be handled. This is accomplished by spreading it upon land or in vats to dry or better by the use of especially designed presses. By the former method it becomes more or less of a nuisance and loses much of its value as a fertilizer through evaporation and exposure to the air. By the use of presses a large percentage of the water is at once removed and the product is a compressed cake which can be handled and stored for some weeks without offense. At works where these sludge cakes are produced it has, however, been found rather difficult to build up a market for them and the income from their sale has not been large. In fact the farmers have, in some cases, refused to haul them away when they could be had without a price.

Broad irrigation and intermittent filtration have great advantages over other processes where suitable land is available. The sewage is applied directly to the soil. Where broad irrigation is the method used, the ground is generally cultivated. The sewage is passed over small level areas in thin sheets or through shallow ditches a few feet apart. An acre of ground is able to purify the sewage of one hundred to two hundred people. This method is in extensive use in Europe. The weight of evidence goes to prove that the sewage farms there are not a nuisance. The health of the operatives is as good as that of any other class of people. The vegetables raised on these farms are of superior quality and are in demand and their sale goes a long way toward meeting the expence of handling the sewage.

In the use of intermittent filtration, no attempt is made to cultivate the ground. Land to be used for this purpose must be porous, thoroughly underdrained and so arranged that the sewage can be applied, first to one portion and then to another. The entire area to be used is divided into several sections, each of which in turn receives the flow and afterwards rests and becomes fit when sewage is again applied to purify it. An acre of ground is by this method capable of purifing the sewage for from 300 to 600 people. Where excessive quantities of sewage are not applied the flow from the drains or through the soil to natural streams or springs is unobjectionable.

In the case of East Orange, New Jersey, the sewage after being charged with a very small quantity of chemicals, viz: 2½ grains of lime and one grain of sulphate of Alumina per gallon is applied to the soil on the principle of intermittent filtration. It descends to under drains

from three to five feet deep and twenty feet apart and is by them conveyed to a small tributary of the Passaic River not far from the water supply intakes of Jersey City and Newark, without objection.

At Medfield, Massachusetts, the sewage from a population of about 500 and the refuse from the straw works located there is discharged upon the surface of a filter bed of about one acre in extent, the natural drainage from which finds its way to a spring about 300 feet down the valley. Analysis of the sewage and of the spring water in respect to ammonia and nitrates show not mere dilution, but purification. Free ammonia and albuminoid ammonia are found in large quantities in the sewage representing organic nitrogenous matter. Oxidation converts the nitrogen into the inorganic form of nitrates. In respect to ammonia this spring water compares favorably with many public supplies. Neither sight, taste or smell detects anything objectionable about it.

The processes of purification by application to the soil may be summarized as follows:

First: Absorption by vegetation of manurial matters.

Second. Mechanical filtration by the soil.

Third. Minute subdivision of the water in the pores of the soil with resulting oxidation or combustion of organic matter.

Fourth. Nitrification or tearing apart of complex organic forms by microscopic life found near the surface of the soil.

If we discharge crude sewage into the Missouri River by gravity flow through the Brush Creek and Blue River Valleys, we will have to convey it from the junction of the two mains at Forty-seventh and Campbell Streets, a distance of about nine miles. The total available fall is from 90 to 100 feet. The average gradient will then be about 1 to 500. Assuming that a location could be made by which this average gradient could be maintained for the entire distance, we have from Flynns Hydraulic Tables based on Kutter's Formula the following results.

Diam. in.	$c\sqrt{r}$	$\sqrt{s}$	v	a	Quantity.		No. of inhabit'nts served.
					Cu. ft. per sec.	Galls. in 24 hours.	
12	35.40	.044721	1.58	0.785	1.24	750,000	3,750
15	42.05	.044721	1.88	1.227	2.31	1,397,000	7,000
18	48.38	.044721	2.16	1.767	3.82	2,310,000	11,500
21	54.29	.044721	2.43	2.405	5.84	3,532,000	17,700
24	60.08	.044721	2.69	3.142	8.45	5,111,000	25,500

These tables are intended to apply to "Cement and Terra Cotta Pipes with imperfect joints in bad order, well dressed stone work and second class brick work." The discharge through smooth vitrified pipes will be 27 per cent. greater. If required to render the service indicated in the above calculation, the smooth pipes would then run about four-fifths full.

It is not probable that this average gradient of one in 500 can be maintained. In that case the capacity of sewers of the sizes mentioned will be somewhat less than as stated. The cost of construction cannot be arrived at with any degree of accuracy in the absence of data on which to base it. I do not, however, believe it will be less than

for 12 in. pipe $1.50 per lineal foot........	$71,280.00
for 15 in. pipe $1.75 per lineal foot........	83,160.00
for 18 in. pipe $2.00 per lineal foot........	95,040.00
for 21 in. pipe $2.25 per lineal foot........	106,920.00
for 24 in. pipe $2.50 per lineal foot........	118,800.00

The above rough approximation is intended to cover the cost of man-holes about once in 600 feet, rock excavation, bridges and right of way. It is plain that to construct an outlet to the Missouri River of sufficient size to serve only the present population would be unwise and it is almost as plain that to construct an outlet now of sufficient size to serve the estimated ultimate population would be a heavy and unnecessary burden to a community already obligated to pay large amounts for completed and necessary public work.

To return to the methods which purify sewage by application to the soil: Their use involves no expensive plant with a constant charge for attendance, which the chemical process requires. The purchase price of the land is the main item. This at present values is not likely to be a bad investment for the city, should it at any time decide to build to the Missouri River. If broad irrigation is the method used, it will probably be found convenient to construct a tank of sufficient capacity to hold the sewage which will accumulate in 24 hours and from which it can be conveyed to any desired portion of the purification area once each day. As already stated the increased income from the sale of the crops will reduce materially the cost of attendance.

If intermittent filtration is found to be more desirable, the under drainage of the land and some grading of the surface will be required. The expense of this preparation will be about $250 per acre. The sewage will be applied through open channels, having gates, the position of which it will be necessary to change once or twice in twenty-four hours. The cost of this service will be nominal.

It will probably be found best at some time in the future to drain to the Missouri River, but for the present and for years to come, I am inclined to believe from the superficial and hasty examination which I

have been able to make in the brief time allowed me for the preparation of this paper that broad irrigation or intermittent filtration, or both methods combined, using for that purpose the land west of Troost Avenue and south of Forty-seventh Street already cultivated by market gardeners, is the solution of the problem.

THE LIGHT-HOUSE SYSTEM OF THE UNITED STATES.

By Edward P. Adams, Member of the Boston Society of Civil Engineers.

[Read January 25, 1893.]

In this paper I give a hasty glance at the history of coast lighting, and the theory of it,—dwelling longer upon the growth of a system in this country. Then follows an account of the organization of the light-house service as it now exists, and a description of the various aids to navigation in use, with illustrations of their typical forms, particularly of the light-house towers. Light-house construction is left to be described at another time.

Much of the following is condensed from Johnson's "The Modern Light-House Service," a publication of the U. S. Light-House Board.

HISTORY.

It is claimed by some that Homer refers to light-houses in the XIX book of the Iliad where Pope's translation reads:—

> "So to-night wandering sailors pale with fears
> Wide o'er the watery waste a light appears,
> Which on the far-seen mountain blazing high
> Streams from lonely watch tower to the sky."

Virgil mentions a light on a temple to Apollo, "which, visible far out at sea, warned and guided mariners." The Colossus of Rhodes erected 300 B. C., is said to have showed from his uplifted hand a signal light. "But the famous Pharos of Alexandria, built about 285 B. C., is the first light of undoubted record."

The light-house at Corunna, Spain, built in the reign of Trajan, and reconstructed in 1634 is believed to be the oldest existing light-house. England and France have towers which were erected and used as light-houses by the Roman Conquerors.

At the present time the light-house system of Western Europe leaves little to be desired. The New World has taken its lesson from the Old and welcomed commerce by its beacon lights.

The famous Cordovan Tower of France, at the mouth of the Geronde, in the Bay of Biscay, was completed in 1611 in the reign of Henry

IV, and after a lapse of 280 years it is still considered the finest light-house in the world, though it has been increased in height.

The erection of Eddystone light-house of Plymouth, England, completed in 1759, made a new era in the construction of light-houses. The fifty courses of granite were so dove-tailed and fastened together that the tower was almost as rigid as if cut out of solid rock; but strong as it was, it became necessary to take it down and rebuild it on a neighboring rock, as that on which it was founded was weakened by constant beatings of the sea. The masonry of the light-house was 76 feet, and the top of lantern, 93 feet above the foundation.

Bell Rock light-house, the next English light-house of a similar nature, is one hundred feet high, and was finished in 1810, at a cost of $300,000.00. The light-house on Skerryvore Rock, off the West coast of Scotland, which cost with the harbor for the tender $435,000.00, was first illuminated in 1844. Another of this nature is the light-house on Bishop Rock off Scilly, one hundred forty-five feet high and cost $182,-500.00.

"Wolf Rock light-house off Lands End, Cornwall, Wales, is the latest great British work and both in its structure and its illumination it combines all the refined improvements." The foundation was commenced in March 1862 and the light-house completed July 1869. In the first season only eighty-three hours of work could be done and the whole time occupied in the building was equal to about one hundred and one working days. The cost was $313,630.00.

"The great distinction between the later towers and their predecessors is that the stones of each course are dove tailed together laterally and vertically so that the use of metal or wooden pins is needless. This method was first used at Hanois Rock, Guernsey."

The list on next page shows the number of lights in each country, according to the latest figures available.

THEORY OF COAST LIGHTING.

"The theory of coast lighting," writes Johnson, chief clerk of the L. H. Board, in his "Modern Light-House Service." "is that each coast shall be so set with towers that the rays from their lights shall meet and pass each other, so that a vessel on the coast shall never be out of sight of a light, and that there shall be no dark spaces between lights. This is the theory upon which the United States is proceeding, and it plants lights where they are most needed upon these lines. Hence from year to year the length of the dark spaces on its coast is lessened or expunged entirely and the day will come when all its coast will be defined from end to end by a band of light by night and by well-marked beacons by day."

LIGHT STATIONS OF THE WORLD. (1885-9.)
From British Admiralty Lists.

Great Britain & Ireland. .	817	United States.	802
Norway.	220	Canada & Newfoundland.	494
Sweden.	295	Mexico & Cent. America.	33
Russia*	154	West Indies.	106
Germany.	179	South America. . . .	167
Denmark.	132	Africa.	219
Netherlands & Belgium.	184	China & Japan. . . .	148
France.	444	Rest of Asia.	328
Spain & Portugal. . .	216	Australia & Tasmania. .	215
Italy.	244	New Zealand.	79
Turkey & Black Sea. .	256	Oceanica.	25
Miscellaneous.	168		
EUROPE.	3477	TOTAL.	5925

(Post Lights in U. S. A. omitted.)

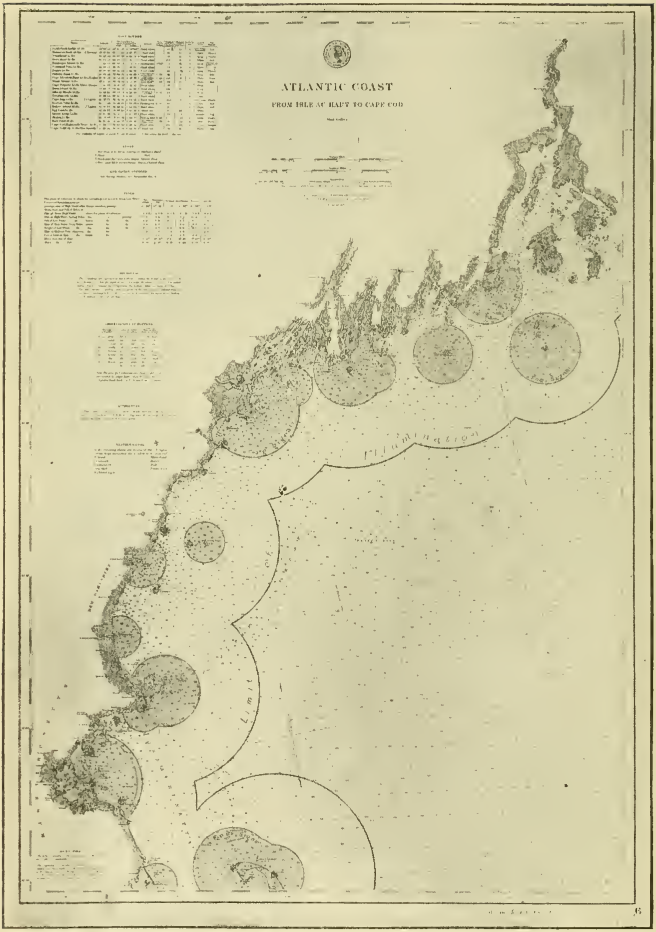
(Mr. Adams then showed and explained a chart of the coast of Maine with limits of illumination of lights and ordinary audition of fog signals.)

FIRST LIGHT-HOUSES IN AMERICA.

The early colonists evidently saw the necessity for beacons to guide vessels to a safe anchorage. The first authentic record of this is in the proceedings of the general court of the Province of Massachusetts Bay. March 9, 1673, is the date of a petition from the citizens of Nantasket for lessening their taxes on account of extra material and labor furnished in building a beacon on Point Allerton; and during the same session, bills from Nantasket were paid for "fier bales of pitch and ocum for the beacon." They were burned in an iron basket on the top of the beacon.

In 1791 the United States expended for its light-house established $22,391.94; in 1890, $3,503,994.12 was appropriated. The total expense for the hundred years was $93,238,925.80.

The first light-house in America was built at the entrance to Boston Harbor in 1715-16, at a cost of L. 2,285 17s 8 1-2d.,—about $11,500. Erected by the order of the general court of the Province of Massachu-


ATLANTIC COAST
FROM ISLE AU HAUT TO CAPE COD
Limit of Illumination

setts Bay, it was supported by light dues of one penny per ton on all vessels except coasters.

Other colonies followed the example of Massachusetts. By act of August 7,1789, the United States accepted session of title to the light-houses on the coast and agreed to maintain them thereafter. There were eight light-houses, and to-day there are light-houses on the same sites. These are Portsmouth Harbor Light, Boston Light, Gurnet Lights, near Plymouth, Brant Point Light, on Nantucket, Beaver Tail Light, Rhode Island, Sandy Hook Light, at the entrance to New York Harbor; Cape Henlopen Light, Delaware and Charleston, S. C. Main Light.

ORGANIZATION.

The lights were first placed under the direction of the Secretary of the Treasury. On May 8, 1792, the office of commissioner of Revenue was established and the superintendence of the lights devolved upon him. Ten years later this office was abolished and the Secretary of the Treasury resumed control of the lights. Eleven years after this the office of Commissioner of Revenue was re-established, and abolished the second time in seven years later in 1820. The duties of this office including superintendence of lights devolved upon the Fifth Auditor of the Treasury.

Mr. Stephen Pleasanton who held that office was the general superintendent of lights for thirty-two years. During this time the number of light-houses increased from fifty-five to three hundred and twenty-five light-houses and light-ships. So far without reference to any general system. In 1837 the Board of Naval Commissioners made a report upon the necessity of new lights. The next year the Senate Committee on Commerce reported upon the need of a better system "of locating, constructing, lighting and managing the light-houses," and $15,000, was appropriated for the purchase and testing of new apparatus. Under the same act the President divided the Atlantic coast into six, and the Lake coast into two districts.

An officer of the Navy was detailed to examine and inspect the light-houses; and a revenue cutter, or hired vessel, was assigned to him. He was to report as soon as possible. Lieutenant Bache's report presented a plan for a new system, somewhat like that which is now actually in operation.

May 25, 1842, the committee on Commerce of the House of Representatives made a careful report on the expenditures of the light-house establishment.

On Jan. 31, 1843, Mr. I. W. P. Lewis, "a civil engineer of high repute," appointed by the Secretary of the Treasury, made a vigorous report upon the condition of a third of all the light-houses, and started quite a controversy. But Congress adjourned before action was taken.

Two years later Lieuts. Jenkins and Bache, detailed from the Navy, were sent abroad to procure information which might tend to the improvement of the light-house system of the United States. They made their report June 22, 1846. As the result of this and the recommendations of Secretary Walker, Congress in 1851 authorized new apparatus and the appointment of a board to inquire into the condition of the establishment.

On Jan. 30, 1852 the Board made an elaborate report of 760 pages, illustrated by 40 plates and numerous wood cuts.

"Every source of reliable information seems to have been explored to reach a true estimate of the merits and defects of our system.

By the act of June 30, 1853, the Light-House Board was organized as it now exists. Johnson in his book says: "This act required the President, immediately after its passage, to appoint two officers of the Navy of high rank, two engineer officers of the Army, and two civilians of high scientific attainments, whose service might be at the disposal of the President, with an officer of the Navy and an officer of the engineers of the Army as secretaries, who should constitute the United States Light-House Board; the Board to be attached to the office of the Secretary of the Treasury, and under his superintendence to discharge all the administrative duties relating to the construction, illumination, inspection and superintendence of light-houses, light-vessels, beacons, buoys, sea-marks and their appendages, and embracing the security of foundations of existing works, procuring illuminating and other apparatus, supplies, and materials of all kinds for building and re-building, and keeping in good repair, buildings, vessels, and buoys of the United States. The Secretary of the Treasury was to be president, but the Board was to elect from its own number a member to act as chairman in the presidents absence. The Board was to meet quarterly, and as much oftener as might be found necessary; and to it were to be transferred all the archives, book-documents, models, drawings, apparatus, returns, etc., belonging to the Light-House Establishment of the United States, together with the clerical force employed on light-house work."

"The Board was required to arrange the Atlantic Gulf and Pacific coasts of the United States into 12 light-house districts, and an officer of the Army or Navy was to be assigned to each as light-house inspector, under its orders."

"The Board was to make and promulgate, with the approbation of the Secretary of the Treasury, rules and regulations necessary for securing an efficient, uniform and economical system of administration. It was to have prepared, by its Engineer Secretary, or other engineer officers of the Army under its orders, all plans, drawings, specifications and estimates of cost of all illuminating and other apparatus, of con-

struction and repairs of towers and buildings. It was to procure by public contract all material for the construction and repair of light-houses, light-vessels, beacons, buoys, etc., and all construction and repairs were to be made under the superintendence of its Engineer Secretary. It was to furnish estimates of all the expenses which the several branches of the Light-House Establishment might require, and to make a full annual report. The members of the Board were to receive no pay for their services other than that they received in the Army, Navy or civil service, and they were prohibited from having any interests in any light-house contracts, as were all others in the light-house service."

"An inspector, who was either an Army or Navy officer, and, as soon as needed, an Engineer officer from the Army were assigned to each light-house district. The Inspectors, under the direction of the Board, were charged with the maintenance of the lights and light-houses, and the discipline of the light-keepers."

"The district Engineers, under the direction of the Board, were charged with building the light-houses, with keeping them in repair, and with the purchase, the setting up, and the repairs of the illuminating apparatus. The chairman with the Naval Secretary and the Engineer Secretary formed the executive committee of the Board. Both Inspectors and Engineers made regular and special reports to the Board, acting always under its direction, and the Board made a full annual report to Congress. The Board assigned its members first to an executive committee, and then divided them into committees on finance, engineering, light-vessels, lighting, and experiments, and placed that one of its members most expert in each particular branch at the head of the committee having charge of that branch. The committee on light-vessels was afterward charged with the care of buoys also, when it was called the "committee on floating aids to navigation." In after years, the committee on location of light-houses was added to the number. The executive committee, consisting of the Chairman and the two Secretaries, were in perpetual session, carrying on the routine business of the establishments, while the other committees met frequently, and the full Board met monthly, or oftener, though required by law to meet but once a quarter."

More in regard to the details of the organization of the light-house service will be found in the third chapter of Johnson's "The Modern Light-House Service," from which the foregoing description has been quoted.

LIGHT-KEEPERS.

The first light-keeper in this country whose appointment is on record was George Worthylake, who was appointed keeper of the light-house at Little Brewster, Boston Harbor, in 1716 at L. 50 per year by

order of the general court of the Province of Massachusetts Bay. When the Federal Government had assumed charge of the Light-House Establishment, the appointment of keepers was made by the President and quite a number of commissions bear the signature of George Washington or Thomas Jefferson, who took great interest in light-house affairs.

As the number of light-keepers increased, their nomination was made by collectors of customs, who were the local superintendents of lights, but the appointment was made by the Secretary of the Treasury. This usage still holds; but the nomination of the Collector is forwarded to the Light-House Board, whose indorsement procures for it favorable or adverse action. The appointment, however, is temporary. It continues only until the candidate has been examined; after which, if he passes, a full appointment is given him. Otherwise, he is dropped from the service.

The appointment of light-house keepers is restricted to persons between the ages of eighteen and fifty, who can read, write and keep accounts; are able to do the required manual labor, to pull and sail a boat, and have enough mechanical ability to make the necessary minor repairs about the premises, and keep them painted, whitewashed and in order. After three months of service, the appointee is examined by an inspector, who, if he finds that he has the qualities needed at that especial station, certifies that fact to the Light-House Board, when, upon its approval, the full appointment is issued by the Treasury Department.

But one grade of keeper is recognized by law, but practically they are divided into a number of grades with pay ranging, with a few exceptions, from $350.00 to $820.00. The lowest salary is $100.00 and the highest is $1,000.00.

At first and second order shore lights, there are two light-keepers. A second assistant is required where there is a steam fog signal in connection with the light. At isolated stations another assistant is added. At a few of the most exposed stations there are three and even four assistant keepers.

Keepers are usually appointed to the lowest grade and promoted or transferred according to merit as vacancies occur. At stations requiring but one keeper, retired sea captains who have families are frequently selected. At fog-signal stations it is the intention to have one keeper or assistant who is able to operate machinery and keep it in repair.

Keepers are forbidden to engage in any business which will take them away from their stations or interfere with the proper and timely performance of their duties as light-keepers. But such work as curing fish, shoe-making and tailoring is allowed, and the light-keeper is sometimes a justice of the peace. They are not allowed to keep boarders.

At stations where there is sufficient land they have a convenient dwelling with fuel house and often a barn: Suitable boats are furnished stations not accessible by land. A kitchen stove is supplied, also a little coal and sufficient kerosine for lights, and good libraries of about thirty (30) volumes are furnished, and exchanged from two to four times a year.

The amount appropriated for the salaries of keepers is at the rate of $600.00 per year amounting to about $700,000.00 for all keepers in the service.

The aids to navigation which are under the control of the Light-House Board are of three general classes.

1. Light-houses and lighted beacons.
2. Beacons, Buoys, Stakes and other Day Marks.
3. Fog-Signals including Whistling and Bell Buoys.

The number of each and their distribution in the United States are shown in the following tables:

AIDS TO NAVIGATION MAINTAINED BY THE LIGHT-HOUSE ESTABLISHMENT, JUNE 30, 1892.—LIGHTS.

ORDER OF LENS.	ATLANTIC AND GULF	PACIFIC.	LAKE.	RIVER.	TOTAL.
Electric.	2	—	2	—	4
First Order.	40	15	—	—	55
Second Order.	16	1	3	—	20
Third Order.	27	4	21	—	52
3½ Order.	3	—	8	—	11
Fourth Order.	156	17	88	—	261
Fifth Order.	110	7	34	—	151
Sixth Order.	55	—	63	—	118
1st. to 6th.	409	44	219	—	672

AIDS TO NAVIGATION MAINTAINED BY THE LIGHT-HOUSE ESTABLISHMENT, JUNE 30, 1892.—LIGHTED AIDS.

AIDS.	ATLANTIC AND GULF	PACIFIC.	LAKE.	RIVER.	TOTAL.
Lens Lantern. . .	49	10	29	—	88
Tubular Lantern. .	265	77	50	1369	1761
Range Lens. . .	16	—	—	—	16
Reflector. . . .	38	—	8	—	46
Light Vessel. . .	27	1	4	—	32
Electric Buoy. . .	7	—	—	—	7
Gas Buoy. . . .	2	—	—	—	2
1st. to 6th. . . .	409	44	219	—	672
LIGHTED AIDS. .	813	132	310	1369	2624

AIDS TO NAVIGATION MAINTAINED BY THE LIGHT-HOUSE ESTABLISHMENT, JUNE 30, 1892. UNLIGHTED AIDS.

AIDS.	ATTANTIC AND GULF	PACIFIC.	LAKE.	RIVER.	TOTAL.
FOG SIGNALS.					
By Steam or Hot Air.	44	23	40	—	107
By Clockwork. .	161	10	16	—	187
Day Beacons. . .	325	94	—	—	420
BUOYS.					
Whistling. . . .	43	19	—	—	62
Bell Buoys. . . .	79	8	2	—	89
Other Buoys. . .	3586	298	402	—	4286
UNLIGHTED AIDS.	4238	452	461	–	5151

Each one of these classes should cover the approach to the whole coast and large lakes and all the broad part of the navigable rivers to form a complete system of light-house service.

The illustrations mounted on these cards show the first light-house in the United States, the present typical light-houses for various situations, typical light-vessels and light-house tenders, also typical foundations which have been required for light-house structures.

In addition to these are illustrations of various kinds of buoys, some of the simpler forms of beacons and photographs of new fog signal machinery for steams whistles.

1. Boston Light-House, the first built on the continent.

2. Brandywine Shoal L. H., the first American L. H., built on piles.

3. Paris Island Range Rear Beacon, an economical structure.

4. St. Augustine L. H., typical brick L. H.

5. Minot's Ledge L. H. Typical stone L. H., in the open ocean.

6. Spectacle Reef L. H. Typical stone L. H., for the great lakes.

7. Tillamook Rock L. H. Typical L. H., on a high isolated rock.

8. Thimble Shoal L. H. Typical screw-pile L. H., in Bays, Sounds and Rivers.

9. Fowey Rock L. H., screw-pile L. H., in the open ocean.

10. Hunting Island L. H. Typical iron L. H.

11. Detroit River L. H. Typical wooden Caisson foundation.

12. Southwest Ledge L. H. Typical tubular iron foundation L. H., for Sounds, Bays and Rivers.

13. Fourteen-Foot Bank L. H. Typical iron Caisson foundation for the open sea.

13a. Lubee Channnel L. H. Section showing foundation and structure.

14. Race Rock L. H. Submarine concrete foundation for furious tide ways.

15. Pollock Rip Light-Ship. Typical first-class light-ship with fog signal.

16. U. S. Steamer Madrono. Typical steam light-house tender.

17. U. S. Steamer Lily and a River Stake Light. Typical river light-house tender and western river light.

18. Buoys and Moorings.

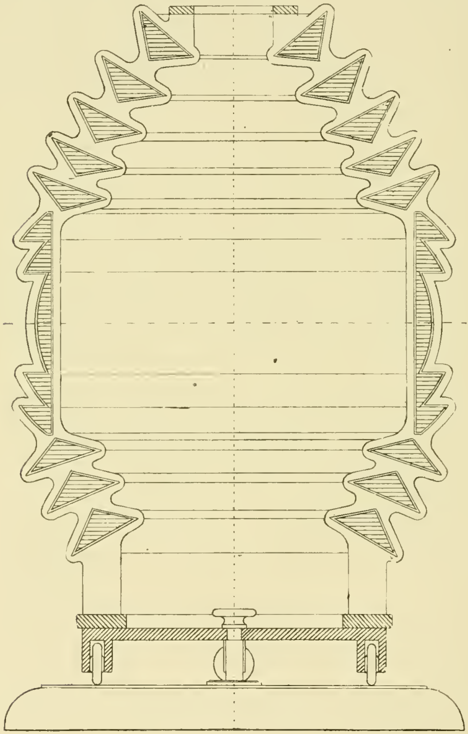
19. Fog signal machinery for steam whistles.

20. Model of tripod 70 ft. high at Channel Rock, Me.

21 and 21a. Photograph and model showing construction of dolphin at Hull, Mass., an economical substitute for iron spindle, when piles can be driven.

ILLUMINATION.

It is a long step from the illumination in 1673 of the beacon on Point Allerton at the entrance to Boston Harbor, by "fier bales of pitch and ocum" burned in open braziers, to the perfected fountain lamps and the first order lens apparatus of to-day. Boston light erected in 1716



SIXTH ORDER LENS.

was first lighted by tallow candles, then followed the spider lamp, burning fish oil, and in 1812 Mr. Winslow Lewis's patent magnifying and reflecting lantern. The reflectors were gradually improved and the magnifiers done away with. When the Light-House Board took control in 1852, the reflectors were replaced by the Fresnel lenticular

apparatus, found so successful in France. This system made a very considerable saving in the oil consumed, requiring about one-fourth as much as for an equally effective illumination by the use of reflectors.

The lenticular apparatus consists of a central powerful lamp around which is a cylindrical arrangement of glass which refracts the rays of light from the lamp either to one horizontal plane or into parallel rays in several required directions.

(Mr. Adams showed a full size sectional drawing of a 6th order lens and explained the concentration by both refraction and reflection at the rays of light from the lamp to a horizontal direction.)

The compound lens may be considered as a simple lens with the unnecessary portions cut away, leaving rings or belts.

"Nothing can be more beautiful than an entire apparatus for a fixed light of the first order," said the great Scotch light-house Engineer, Mr. Alan Stevenson. "It consists of a central belt of refractors, forming a hollow cylinder six fect in diameter and thirty inches high; below it are six triangular rings of glass, ranged in a cylindrical form and above a crown of thirteen rings of glass, forming by their union a hollow cage, composed of polished glass, ten feet high and six feet in diameter. I know of no work of art, more beautifully creditable to the boldness, ardor, intelligence and zeal of the artist."

If it is a shore light, a concave mirror in place of the lens on the land side utilizes the light on that side. White and red are the colors of all but a very few of the lights. The lights have one of the following characteristics. 1st. Fixed white; 2nd. Flashing white (from once in two minutes to once in every five seconds;) 3rd. Fixed white varied by flashes; 4th. Two or three lights; 5th. fixed red; 6th. Flashing red; 7th. Fixed red varied by a red flash; 8th. Fixed white varied by a red flash; 9th. Flashing red and white (either alternately; or two white, one red; three white, one red, etc.;) 10th. White with one or more red sectors; 11th. green light.

There are six orders of lens lights and five kinds of reflector lights, the latter including the old and new light-vessel lights. (A diagram of intensities was here shown and explained. The diagram also included full size sections of the wicks of each order of lamp.) The table, page 523, gives the figures.

The lens of the first order light is 6 feet in diameter and costs alone from \$4,250 to \$8,400; second order, 4 feet, 7 inches in diameter, costs from \$2,760 to \$5,530; third order, 3 feet 3⅜ inches diameter, costs \$1,475 to \$3,650; fourth order, 19⅝ inches diameter, costs \$350.00 to \$1,230; fifth order, 14½ inches diameter, costs \$230. to \$840.; sixth order, lens, 11¾ inches diameter, costs \$190. to \$315.

In flash lights, the lens or a part of it may revolve, or an extra vertical panel or panels may revolve around the fixed lens.

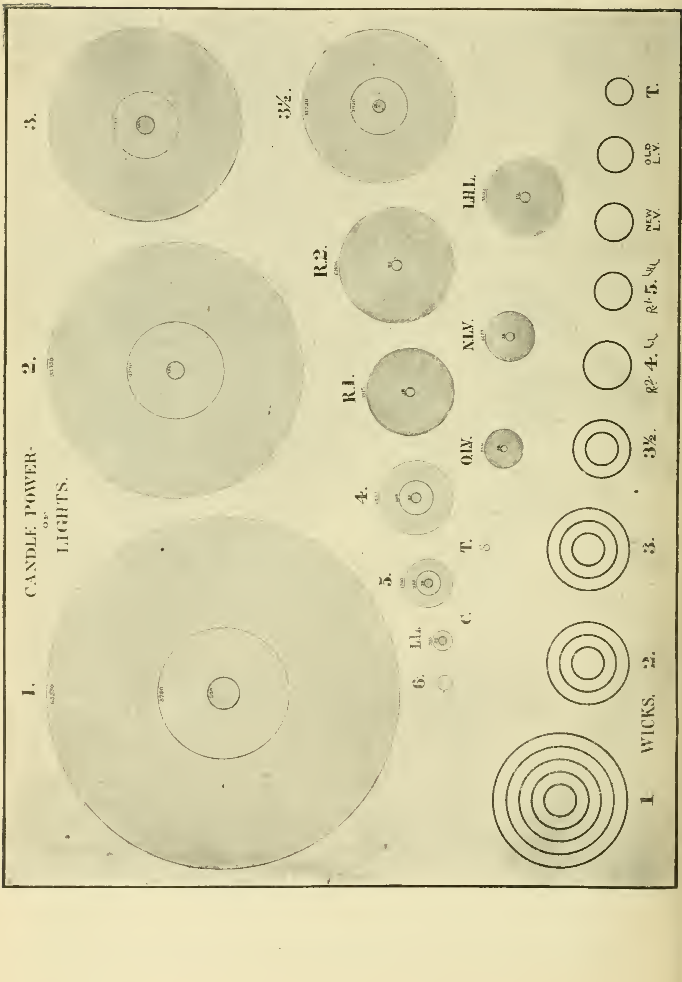

CANDLE POWER OF LIGHTS.
1.
2.
3.
3½.
4.
5.
6.
L.L.
T.
C.
O.L.V.
R.1.
R.2.
N.L.V.
L.H.L.
WICKS.
1
2.
3.
3½.
R2. 4.
R1. 5.
NEW L.V.
OLD L.V.
T.

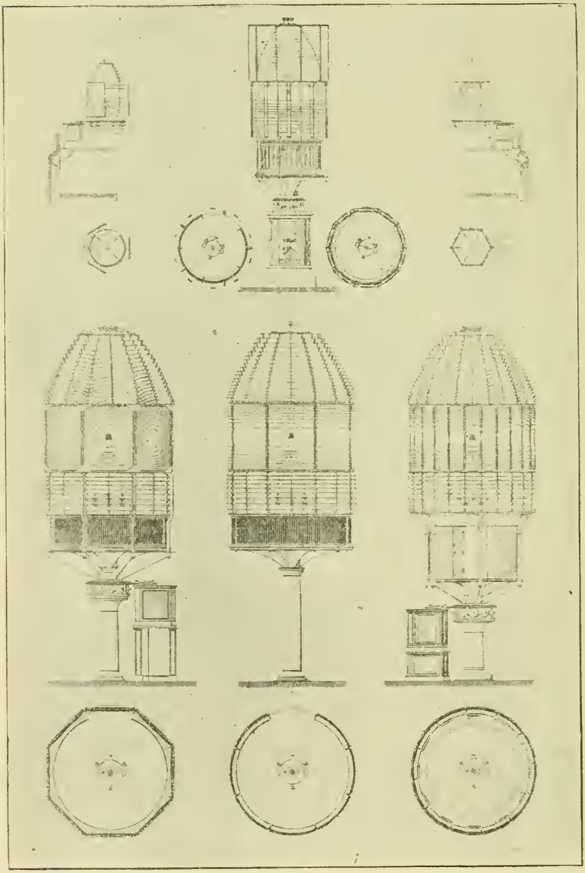
TABLE GIVING CANDLE POWER OF EACH OF LAMPS USED IN THE LIGHT-HOUSE SERVICE AND APPROXIMATELY ITS INTENSITY WHEN USED IN ITS APPROPRIATE LENS APPARATUS.

Illuminating Apparatus. Order.	Name of Lamp.	Candle Power of Lamp.	Candle Power of Fixed Light.	Candle Power of Flashing Light.	No. of Wicks.	Sizes of Wicks in Inches. No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	Expenditure of Oil per Quarter. 1st Qr.	2d Qr.	3d Qr.	4th Qr.	Consumption of Oil. Per Hour.	Per Annum.
															Gills.	*Gal.*
1st	Funck's Float Lamp	500	8780	63830	5	1″	1 13/16″	2 5/8″	3 7/16″	4 5/16″	596	443	475	642	16	2156
2d	do	163	4790	33350	3	1″	1 13/16″	2 5/8″			182	135	145	195	4.80	657
3d	do	163	2240	19040	3	1″	1 13/16″	2 5/8″			182	135	145	195	4.80	657
3d (old)	do	78	1930	15380	2	1″	1 13/16″				75	54	60	81	2	270
3½	do	78	1620	11720	2	1″	1 13/16″				75	54	60	81	2	270
4th	Funck-Heap Lamp	52	598	2842	1	1½″					59	44	47	64	1.50	214
5th	Funck's Tubular Lamp	38	298	1200	1	1 3/16″					37	28	30	40	1	135
Lens Lantern	do	32	203		1	1 3/16″					26	20	21½	27½	0.70	95
No. 1 Range Lens	do	38	3915		1	1 3/16″					37	28	30	40	1	135
Locomotive Headlight Lantern	Funck-Heap Lamp	52	3092		1	1½″					55½	41½	44½	60½	1.50	202
Tubular Lantern			12		1	⅞″					10½	8½	9½	11½	0.30	40
Light-Vessel Lantern Lamp with reflectors	Funck's Tubular Lamp	38	1275		1	1 3/16″					37	28	30	40	1	135
Old Light-Vessel Lamp with reflector		18	760		1	1⅛″					19	13	16	20	0.50	68

NOTE.—Candle power of 1st, 2d, 3d, and 3½ order fixed and flashing lights was obtained by calculation; the candle power of all others in above table was obtained by actual measurement.

The United States Light-House Establishment still orders its lenticular apparatus from the French houses of Henri Lepaute, Babier & Fenestre, and Sautter, Lemonier et Cie.

(Mr. Adams showed sectional drawings of the lamps in use.)



ILLUMINATING APPARATUS.

The illuminants that have been used in the United States, since the use of candles in the light-houses was discontinued, are fish oil to 1812, sperm oil to 1861, colza oil to 1867, lard oil to 1879. From 1880 to 1884 kerosine was gradually substituted for the lard oil. The highest price paid any one a year for oil was in 1875, $167,575. for lard oil; the least recently was in 1888, $10,490. for lard oil and $20,059. for mineral oil. The lowest price per gallon, 6¼ cents. The number of gallons of oil purchased in 1889 was 347,960.

Gas has been tried. It is now used at three stations from city works, by compressed gas at ten lights, one gas buoy, and one lighted beacon. The latter is in New York Harbor on Dry Romer Shoal. An iron pier 30 feet in diameter and 16 feet high is surmounted by a skeleton iron tower 25 feet high. The fixed white light of the fifth order is supplied with gas from a tank which holds ninety day's supply, so that no keeper is needed. The pier, tower and apparatus cost less than $15,000. The gas buoy is in Boston Harbor. It holds ninety day's supply.

A combination gas machine is used to furnish the light to some of the stations on the north western lakes. It has worked so well that it will probably come into more general use.

Experiments have been made with the electric lights. The tallest skeleton iron tower erected by the United States Light-House Service was at Hell Gate, New York, in 1884. Its height was 255 feet. It cost $11,000; had nine electric lights of 6,000 candle power each. At night when lighted the effect was grand, but the light dazzled the pilots and prevented them from seeing objects beyond the circle illuminated. And the shadows thrown looked like obstacles. So the light was discontinued.

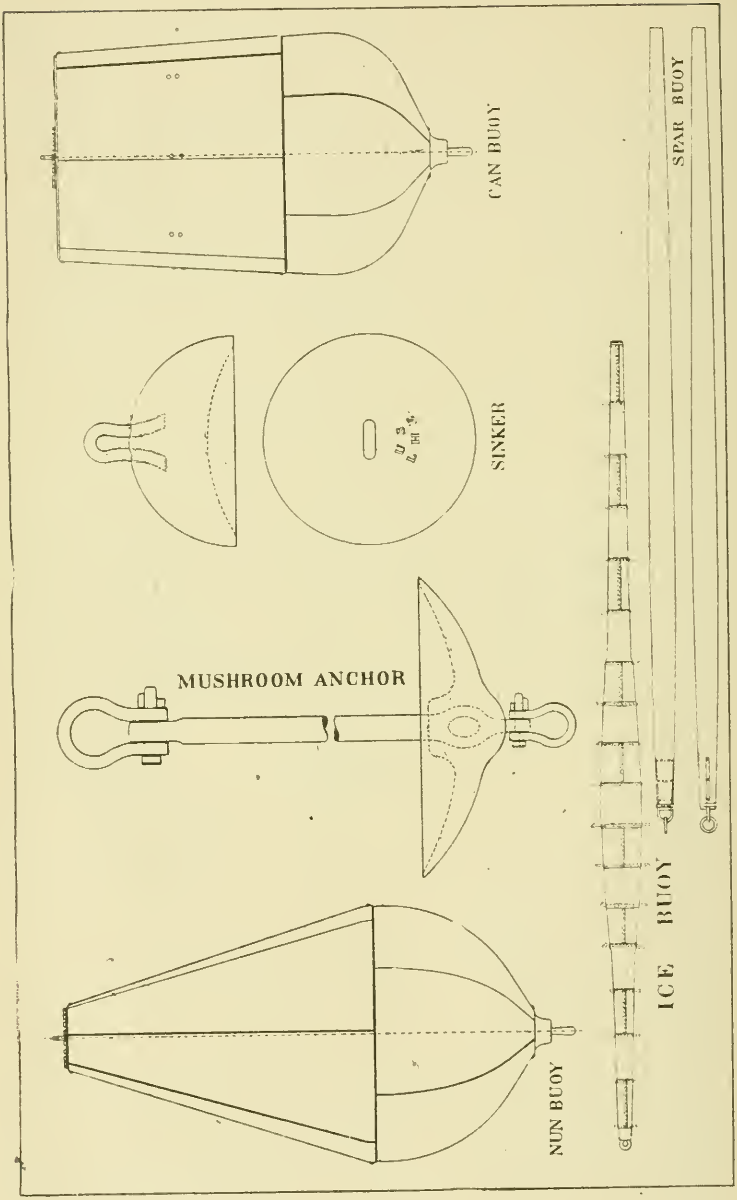
The statue of "Liberty enlightening the World" is under the care of the Light-House Board and is lighted by electricity. Nine duplex lights in the torch at a height of 305 feet are visible 24½ miles at sea. Five single lights, shielded from the water side, in the fort at the base of the statue, illuminate the statue itself.

A system of six lighted buoys at Gedneys channel entrance to New York Harbor are lighted by electric lights of 100 candle power. Cables run to the power house. Sandy Hook east beacon is lighted by electricity. Electricity is likely to be used at the primary sea coast stations at no distant day.

DAY MARKS.

The term Beacons includes all the aids to navigation built upon the ground or ledges and includes light-house towers which serve as beacons by day.

Stone beacons and iron spindles, usually surmounted by an iron cage or ball, wooden cask or wheel with wooden pendants, wooden tripods, sometimes surmounted by a special day mark, and wooden


CAN BUOY
SINKER
U S L H S
MUSHROOM ANCHOR
NUN BUOY
ICE BUOY
SPAR BUOY

dolphins made of five piles, as shown in these photographs, are all included under this class of day-marks.

Buoys are floating aids or day-marks. The various kinds are better shown by illustration than by description.

They are nun buoys, first, second or third class; can buoys, first, second or third class; cone buoys, spar buoys of wood or of iron: ice buoys; bell buoys and whistling buoys. They are all anchored by chains or wire ropes to sinkers or to anchors and show by their color and number their positions on the charts.

In conformity to the revised statutes of the United States, the following order is observed in coloring and numbering the buoys along the coasts, or in bays, harbors, sounds, or channels, viz:

(Read from Buoy book last half of first page.)

1. In approaching the channel, etc., from seaward, red buoys, with *even numbers*, will be found on the *starboard* side of the channel, and must be left on the *starboard* hand in passing in.

2. In approaching the channel, etc., from seaward, *black buoys* with *odd numbers*, will be found on the *port* side of the channel, and must be left on the *port* hand in passing in.

3. *Buoys* painted with *red* and *black horizontal stripes* will be found on *obstructions*, with channel ways on either side of them, and may be left on either hand in passing in.

4. *Buoys* painted with *white* and *black perpendicular stripes* will be found in *mid-channel*, and must be passed close to avoid danger.

Perches, with balls, cages, etc., will, when placed on buoys, be at turning-points, the color and number indicating on what side they shall be passed.

Different channels in the same bay, sound, river, or harbor will be marked, as far as practicable, by different descriptions of buoys. Principal channels will be marked by nun buoys; secondary channels by can buoys; and miner channels by spar buoys. When there is but one channel, nun buoys, properly colored and numbered, are usually placed on the starboard side, and can buoys on the port side of it.

Day-beacons, stakes, and spindles (except such as are on the sides of channels, which will be colored like buoys,) are constructed and distinguished with special reference to each locality, and particularly in regard to the back-ground upon which they are projected.

FOG SIGNALS.

During fogs and at dangerous places distant from lights, sound-signals are necessary to guide mariners in a safe course.

Guns or cannons, rockets and gongs, have been used for these signals, but have not proved very satisfactory.

The fog-signals now in use are steam sirens, steam whistles, condensed air trumpets, whistling buoys, bell buoys, bells struck by ma-

chinery and bells struck or rung by hand in answer to signals. The whistling-buoy and bell-buoy being automatically sounded by the motion of the waves are useful to mark dangerous places away from light stations, at all times.

Bells are in use at most of the light stations. Those run by machinery are actuated by clock-work made by Mr. Stevens of Boston, and are arranged to indicate their location by the time interval between the single or double strokes of the bell.

Brown's bell-buoy, invented by an officer of the Light-House Establishment, consists of a decked and weighted iron buoy 6 feet, 6 inches across the deck, with a frame-work of 3 inch angle-iron 9 feet high. The 300 pound bell is rigidly attached to the top with a radial grooved iron plate just below it. A cannon ball rolling on the plate tolls the bell when there is any wave motion. They cost, without fittings, mooring-chains and sinkers, about $300. each.

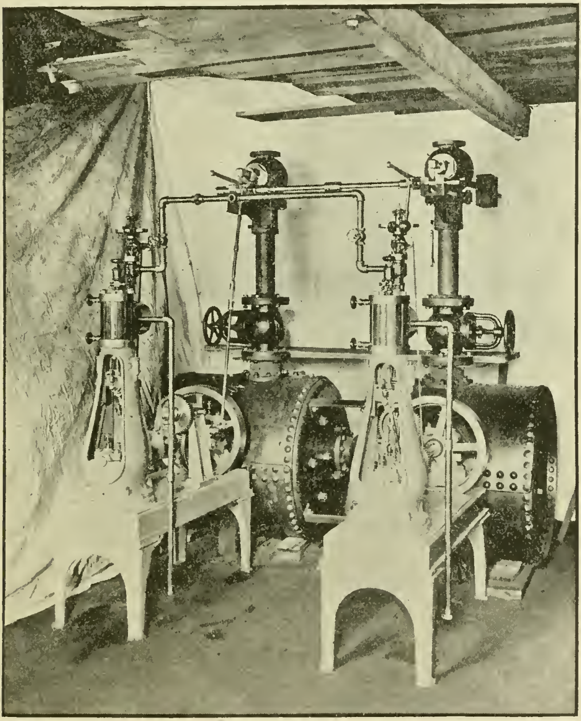
The whistling buoy was patented by J. M. Courtenay of New York. It consists of an iron pear-shaped buoy 12 feet wide, for the largest size, and floating 12 feet out of water, with an inside tube 33 inches across, extending through the bottom of the buoy to a depth of 32 feet into water free from wave motion. The tube is open at the lower end, but at the top is closed with the exception of three holes, two being air inlets and a middle one the outlet by a 2½ inch pipe to the 10 inch locomotive whistle which surmounts the buoy. As the buoy rises the water sinks relatively in the tube, and as the buoy sinks the water rises forcing the air through the whistle. This is the largest of the 4 sizes and weighs 12,000 pounds. The smallest whistling buoy is six feet in diameter and weighs but 2,000 pounds. "These buoys cost about $1100.00 each and their mournful sound can at times be heard 15 miles." But there are aberrations in the sound of all fog-signals, that are hard to explain, that cause them to be inaudible at places scarcely a mile distant.

The locomotive whistle on account of its sharpness or shrillness makes a good fog-signal. Its use for this purpose was first suggested about 50 years ago by Mr. A. Gordon, C. E. It was first practically used as a fog-signal at Beaver Tail Point, Narragansett Bay, erected by Mr. Daboll under the direction of Professor Henry, then chairman of the Light-House Board. The steam at high pressure passing through a circular slit against the edge of the thin metal bell of the whistle causes a strong and rapid vibration.

Difference in pitch in the sound produced is made by changing the distance between the steam orifice and the edge of the bell. The sound is diffused equally on all sides but is strongest in the plane of the edge of the bell. The diameter of the bell is from 6 inches to 18 inches, 10 inches being the most common for fog-signals.

(The Crosby Automatic fog-signal, cylinder 8″ × 2″, cost $200., was mentioned.)

The Daboll trumpet was invented by C. L. Daboll, of Connecticut. The largest trumpet is 17 feet long, 3½ inches in diameter at its throat and 38 inches across at its mouth. Connected with this is a resounding cavity and a steel tongue or reed 10 inches long, 2¾ inches wide, 1



FOG SIGNAL MACHINERY FOR STEAM WHISTLES.

inch thick at its fixed end and ¼ inch at its free end. Air is condensed in a reservoir and driven through the trumpet by hot-air machinery,—the Ericson hot-air engine,—at a pressure of from 15 to 20 pounds. It does not require so much power as the steam whistle, but it more fre-

quently requires repair, and more skillful management is necessary to prevent deterioration in the sound. It is best suited to a station where water cannot be readily procured.

The siren invented by Cagniard de la Tour was adapted to use as a fog-signal by A. and F. Brown, of New York, under the direction of Professor Henry. A first-class fog-siren has a trumpet like the Daboll trumpet. The sound is made by driving the steam through the radial slits in a fixed and a rapidly revolving disk placed in the throat of the trumpet. There are 12 radial slits in each disk and the moving disk revolves 2,400 times in a minute. Thus 480 vibrations per second are produced. A pressure of 72 pounds of steam is required and under favorable circumstances the first-class steam siren can be heard from 20 to 30 miles. It is made in various sizes.

From the results of experiments made by General Duane the power of the first-class siren, the 12 inch steam-whistle and the first-class Daboll trumpet were expressed thus: Siren, 9; whistle, 7; trumpet, 4; but the relative expenditure of fuel; siren, 9; whistle, 3; trumpet, 1; and the relative economy of fuel, siren, 1; whistle, 2½; and trumpet 4.

Length of blast and varying intervals between blasts in these three kinds of fog-signals indicate to the mariner the location of the fog-signal he hears.

The 90 steam and hot air fog-signals of the United States have cost about $7500.00 each, and the yearly expense of maintaining them is about $1250.00 each.

As has been said, the sound of fog-signals are subject to aberrations not easy to explain, so that they may be heard loudly where we would expect them to be heard faintly, and heard faintly or not at all, where we would expect them to be heard loudly.

It seems proved that the mariner approaching a fog-signal from the windward, should go aloft, and when approaching from the leeward, he should go as near the surface of the water as possible, to pick up the sound of a fog-signal most quickly.

The mariner should not assume—

1. that he is out of hearing distance because he fails to hear the sound of a fog-signal,

2. that he is a great distance from it because he hears it faintly; nor

3. that he is near it because he hears the sound plainly;

4. that he has reached a given point in his course because he hears the fog-signal at the same intensity that he did when formerly at that point; nor

5. that he has not reached this point because he fails to hear the fog-signal as loudly as before, or because he does not hear it at all;

6. that the fog-signal has ceased sounding because he fails to hear it even when within easy ear shot;

7. that the aberrations of audibility which pertain to any one fog-signal to pertain any other fog-signal.

The mariner should not expect to hear a fog-signal as well,

1. when the upper and lower currents of air run in different directions; that is, when his upper sails fill and his lower sails flap, etc.;

2. when between him and it, is a swiftly flowing stream, especially when the tide and wind run in opposite directions;

3. during a time of electric disturbance:

4. when the sound must reach him over-land as over a point or an island. When there is a bluff behind the fog-signal he should be prepared for irregular intervals in audition; he might hear it at 2, 4, 6, etc., miles from the signal and lose it at 1, 3, 5, 7, etc., miles, or at any other combination of distances, regular or irregular.

BOOKS.

In this paper I have drawn freely from Johnson's, "The Modern Light-House Service." The other books that may be consulted on this subject are Heaps, "Ancient and Modern Light-Houses," Eliot's "European Light-House System," "Barnard on Light-Houses," Findlay's "Light-Houses of the World," and Renaud's "Illumination and Beaconage of the Coast of France." The latter, finely illustrated, was translated and printed for the use of the Light-House Establishment.

The regular publications of the Light-House Board are:—

1. "List of Lights and Fog-Signals," with illustrations,—one from "Atlantic and Gulf Coasts," and one from the Great Lakes, Pacific Coast and the Mississippi River System.

2. "List of Beacons, Buoys, and Daymarks,"—one for each of the sixteen Light-House districts.

3. "Annual Report of the Light-House Board to the Secretary of the Treasury." The appendices to these reports, occupying often a third of the volume, include many valuable illustrated reports on construction, maintenance and experiments.

NOTE.—The discussion of the above paper will be given in the November issue.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

BOSTON SOCIETY OF CIVIL ENGINEERS.

SEPTEMBER 21, 1893. A regular meeting of the Society was held at its rooms 36 Bromfield Street, Boston, at 7:45 o'clock P. M.

President J. R. Freeman in the chair. 87 members and 24 visitors present.

The record of the last meeting was read and approved.

Mr. William E. Foss was elected a member of the Society.

The committee appointed to prepare a memoir of James B. Francis submitted its report, which was read by Mr. FitzGerald.

Mr. Doane presented a memoir of McGee Grant, which was read by the Secretary.

The Treasurer reported that he had invested with the approval of the Board of Government, $1,000 of the Society's permanent fund in a first mortgage on real estate in East Boston, and on motion of Mr. L. F. Rice, the action of the Treasurer was approved.

Mr. George S. Rice exhibited a number of photographs showing the wreck of the Chester Bridge on the B. & A. R. R., and gave a short account of the accident. A number of photographs kindly loaned by the railroad company was also exhibited.

President Freeman then opened the discussion of the evening on the Construction of Reservoir Embankments, by describing with the aid of diagrams and photographs, the dam at Portland, Me., which recently gave way

Prof. William Watson spoke briefly of the Torcy Neuf Reservoir Dam in France, and read a description of this reservoir from the report of the U. S. Commission to the Paris Exposition.

The Secretary read a communication from Mr. Clemens Herschel on the construction of reservoir embankments.

Prof R. H. Richards spoke of the methods used by mining engineers and metallurgists for sorting and sizing materials, and suggested that similar methods might be adopted for defining the clay and gravel used for puddle. He also described the "Fall tube" which might be used for finer particles which could not be sized by sieves.

The President read a short letter from Mr. J. H. Harlow, of Pittsburgh, giving his experience in building reservoir embankments where no water was used, the materials being put on in thin layers and compacted by grooved rollers.

After a short description by Mr. FitzGerald of the dams built by the City of Boston at its storage reservoirs, the Society adjourned.

S. E. TINKHAM, Secretary.

CIVIL ENGINEERS' SOCIETY OF ST. PAUL.

NOVEMBER 6, 1893. The regular meeting of the Civil Engineer's Soceity of St. Paul was held at 8 P. M. Present eight members and twenty-four visitors.

President Wilson introduced Maj. J. W. Howard of the Barber Asphalt Paving Co., who delivered a two hour lecture on asphalt. its chemistry, sources and uses.

The substance of his address will be found in the coming report of Mr. F. J. V. Skiff, Chief Department of Mines and Mining, World's Columbian Exposition.

C. L. ANNAN, Secretary,

ENGINEERS' CLUB OF ST. LOUIS.

385TH. MEETING, OCTOBER 4, 1893. The club met at 8 p. m. at the club rooms, Vice-President Crosby in the chair, and nineteen members present.

The minutes of the 384th. meeting were read and approved.

The Executive Committee reported the approval of Frank B. Maltby for membership.

Mr. Frank B. Maltby was elected a member of the club.

The following were proposed for membership: A. W. Dickens, C. G. Reel, A. Schnadelbach and A. M. Lockett.

Mr. E. A. Hermann then read the paper of the evening on "Bracing a Tunnel in Soft Material." A tunnel 1435 feet long was built at North Bend, O,, near Cincinnati, about 1840, for the Cincinnati and Whitewater canal. The material encountered was a mixture of river sediments containing considerable water, and causing some difficulties in construction. About 1863 the canal was abandoned, and the right of way purchased by the Cincinnati & Indianapolis Railroad, now a part of the Big Four system. In March, 1884, an extraordinary flood in the Ohio River nearly filled this tunnel with water, and after it receded a short piece of the tunnel about 80 feet long showed a deformation of its section, the side walls being slightly pressed in and the arch flattened, and this deformation threatened to increase. The difficulty was promptly remedied by the system of bracing shown on the drawings. No further movement of the walls of the tunnel took place after they were braced for the following three years, when the extension of the double track over this part of the railroad necessitated either an enlargement of the tunnel or a realignment of the railroad around it. The latter plan was adopted as the cheapest and most satisfactory of the two, and after its completion the track through the tunnel was abandoned.

Discussion followed by Messrs. Wheeler, Crosby, Russell, Colby, Moore, Johnson, Kinealy, Wise, Flad, Baier and Dean.

Mr. George S. Morison presented to the club a valuable report on "The Nebraska City Bridge."

A vote of thanks was given to Mr. Morison for his contribution.

Mr. Bruner presented drillings of the nickel armor plate.

For the next meeting a paper by Mr. D. A. Molitor on "Landslides" was announced.

Adjourned. ARTHUR THACHER, Secretary.

WESTERN SOCIETY OF ENGINEERS.

306TH. MEETING, OCTOBER 4, 1893. The 306th. meeting of the Society was held at the "Joint Engineering Headquarters," No. 10 Van Buren Street, Wednesday, October, 4, 1893, at 8 p. m. President Robert W. Hunt in the chair and 20 members, present.

The reading of the minutes of the last meeting was dispensed with.

On calling the meeting to order the President explained the action of the Board in not conforming to the vote of the Society on Mr. Greeley's motion, at the last meeting, was due to the Board's inability to reconcile such action with the By-laws.

He also informed the Society on the matter of the special meeting and in accordance with a letter from Capt. Jaques he asked the authority of the Society to call the meeting for Monday, October 16, to hear the paper on "Modern Gun Making."

It was then voted to call a special meeting for Monday evening, October 16th.

The Secretary reported for the Board of Directors the election of the following to membership:

Messrs. Walter S. Dole and Wm. H. Jones.

The following applications were also received and placed on file:

Messrs. Jas. F. Lewis, A. P. Vedel, H. V. DeHart.

The President for the Board of Directors presented some proposed Amendments to the Constitution and By-Laws which provided the discussion for the evening.

Adjourned. JOHN W. WESTON, Secretary.

SPECIAL MEETING, OCTOBER 16TH. 1893. A special meeting was held by the Society at 10 Van Buren Street, on Monday, October 16, 1893, at which a paper on "Modern Gun Making" was read by Capt. W. H. Jaques, Ordnance Engineer, of Bethlehem, Pa. The author was introduced by Capt. Robert W. Hunt, President of the Society, and the paper which was illustrated by the Stereopticon, was received with marked attention by a large gathering. After the paper the company adjourned to participate in the regular Monday Evening Reception of the Joint Engineering Societies.

JOHN W. WESTON, Secretary.

MONTANA SOCIETY OF CIVIL ENGINEERS.

OCTOBER 14TH. 1893. The regular monthly meeting of the Montana Society of Civil Engineers, was held Saturday evening, October 14, at the office of Sizer & Keerl, Atlas Building.

There were present: Messrs. Hovey, Keerl, Haven, Reed, Harper, McNeill and Foss; President Haven presided.

The minutes of meetings held June 24th., July 8th., August 12th., and September 9th., were read and approved.

The Secretary read a letter from Mr. E. H. Beckler thanking the Society for the honor it had conferred on him by its action in electing him to Honorary Membership. He reviewed the progress of Engineering in Montana since the organization of the Society July 5th. 1887, and predicted that the greatest work of Montana Engineers in the future would

be found in the construction of irrigation works for the development of the Agricultural resources of the State.

Mr. Foss proposed the name of Joseph T. Dodge for election to Honorary Membership, and stated that Mr. Dodge had been the first president of the Society, and was an engineer of great experience, whose work had been largely connected with the development of Montana, but who had now retired from active engineering work.

The Secretary was instructed to notify the members that Mr. Dodge's name will be voted on at the next regular meeting.

Mr. Joseph H. Harper, of Butte, read a paper on the Butte smoke problem. Mr. Harper proposes to construct two main flues to convey the smoke and sulphur fumes to stacks, one located about two miles south-west and the other three miles north-east of the city. The cost of these flues and stacks would not exceed $500,000.

Mr. Harper exhibited photographs of flues recently constructed by the Omaha and Grant Smelting and Refining Co., at Denver, in which porous terra cotta lumber was used for the covering of the flue, under what is known as the Lee patent.

Mr. Harper believes that if these flues were constructed the smoke nuisance would be almost entirely abated.

No further business offering, the Society thereupon adjourned.

G. O. Foss, Secretary.

November 11th. 1893. President Haven presiding. There were present five members and three visitors.

The minutes of the meeting held October 14th. were read and approved.

An application for membership was received from Soren T. M. B. Kielland and referred to Trustees.

Owing to the small number of members in attendance, the matter of the election of Joseph T. Dodge to Honorary Membership was postponed until the next regular meeting.

On motion of Mr. Relf, the President was instructed to appoint a committee of three to make arrangements for the annual meeting to be held January 13th. 1894.

The Secretary then read a paper by Mr. Chas. Tappan of Livingston, Mont.. on irrigation from the Yellowstone River. Mr. Tappan described several ditches which have already been constructed taking water from the Upper Yellowstone.

He called attention to the limited area that could be irrigated at a reasonable cost per acre, by ditches taken from the main river, and reached the conclusion that most of the lands in the Yellowstone Valley must be irrigated by canals from the branch streams.

In the discussion that followed, Mr. Foss said, "It is probably true that most of the land on the south side of the Yellowstone can be more cheaply irrigated from the tributary streams, but I believe there are two large tracts of land that could be successfully irrigated by canals taken from the main river. One of these tracts comprises about 30,000 acres, and it is situated on the south side of the river near Forsythe, and the other a large area of second bench land on the north or west side between Glendive and the mouth of the river. The latter, however, would be hard to reach, owing to the slight fall of the river below Miles City. These are large tracts, and would require considerable capital to construct suitable

canals, but I believe water could be put on to either of them at a reasonable cost per acre. There is another possible canal which may or may not be practicable, but which, if constructed, would cover a large area of high mesa lands on the north side of the river near Billings. It would probably require a canal 150 miles in length, at a cost of at least $1,000,000, and I am unable to state the amount of land that might be covered.

The construction of such a canal is not likely to be undertaken in the near future, however, and except for the two tracts which I have mentioned above, Mr. Tappan's conclusion is undoubtedly correct."

Mr. Reeder presented to the Society a number of questions in regard to the state statute for measuring water, which the Secretary was instructed to have printed and sent out for discusssion at the Annual Meeting.

No further business offering, the Society thereupon adjourned.

G. O. Foss, Secretary.

ASSOCIATION OF ENGINEERING SOCIETIES.

ORGANIZED 1881.

Vol. XII. November, 1893. No. 11.

This Association, as a body, is not responsible for the subject matter of any Society or for statements or opinions of any of its members.

THE LIGHT-HOUSE SYSTEM OF THE UNITED STATES.

BY EDWARD P. ADAMS, MEMBER OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

(*Continued from October Issue.*)

DISCUSSION.

THE PRESIDENT:—The gentleman whose guests we have been this afternoon has consented to add to our obligations by supplementing Mr. Adams' paper with some statements. I have the honor of presenting Major W. R. Livermore, Engineer Corps, U. S. A.

MAJOR LIVERMORE:—I appreciate very deeply the high compliment you paid me by going down the Harbor to-day; and I am sure that the attractions were solely personal, and that it was not for escaping the heat of the city that you came down.

Our little trip to-day has established a sort of mutual confidence between us. We know that our interests, purposes, desires, aspirations, are all alike: and if I should ever have occasion to make a voyage to the North Pole I should depend on having a large delegation from your Society to accompany me, knowing you would all like to go there. I have made a great many very pleasant acquaintances to-day and renewed a great many; not only among your own number, but I was glad to have this opportunity of meeting your guest from Philadelphia. I do not want to let the evening pass without something more than a casual expression of my opinion about his book. We all know of this pocket-book. We all know, also, that this pocket-book is a terror to the esoteric mathematician; and it is rightly so, and I want to speak of

it in this way. I think it marks a step, that it is in some respects an indication of the tendency of scientific research, that is, a tendency to put the results in such form that they will be intelligible to others not working exactly in the same line. Now the tendency of many of the predecessors of this kind of book was to conceal what they had to say under symbols which meant a great deal to them. Now Mr. Trautwine's book is intended, and I think you will agree that it does tell the engineer something the engineer wants to know about the subject. A great many others were intended to let the engineer know the author knew something about the subject that he could not possibly find out unless he read the book through from beginning to end, and then further, unless he looked through a great many of the text books referred to there. The reason I speak of it particularly is because I think that in some other sciences than mathematics we have had the same trouble. There was a tendency in the past generation to bury things under the symbols of the art. I hope we will all try to aid in the movement that Mr. Trautwine has established in engineering so that it may be applied to all our sciences.

Now I am not going to trespass on your time by going into the details of our light-house work. I have listened to the paper with a great deal of interest, but it has more especial interest to me from the fact that many of these things have been subjects that Mr. Adams and myself have been talking about. I think in a society of this sort what we want is an outline of what we are doing, so one man can find out what another is doing, and then outside we can talk it over. We are all working in the same channels in some respects, and in different channels in others.

Now Mr. Adams has described our light-house service and spoken of it in an excellent way: at the same time some other points may be interesting. The chief merit of the light-house service is conservatism. It is more important to keep a light going right along with a faint flame than to have it burn brilliantly for a while and then be liable to go out. On the whole, the tendency is toward conservatism. Still it has a future. It is not stationary work at all. We are progressing: we are looking forward and changing and advancing. Something of this tendency is indicated by what Mr. Adams has said. The first question that is always put to a light-house engineer is, "Why don't you use electricity? This is the age of electricity." And that I suppose he has to answer almost every day. The reason we do not use electricity is because we get along very well with something else. The first order lamp can be seen in clear weather as far as the curvature of the earth will allow it to be seen, and that light can be maintained at slight expense, and it can be maintained constantly. An arc light, is liable to go out sometimes, and when it does go out it takes longer to

light it than the old lamp. Its first objection is its uncertainty.

Another objection to it is its great expense. It is a great expense to keep the machinery up. You have to employ a higher class of men, a more educated class of men, for light-keepers. It would be a long time before they were trained, and then highly educated men do not make good light keepers. Such a man wants to philosophize a little; and if we had a distinguished engineer to run an electric machine, who knows but that he would discover a new theory of electricity, and while doing so a ship might run aground. Therefore we don't want to have a class of men who know too much for light keepers. But we will eventually employ electricity in lights of the first order. It gives a stronger light and it is better in a good many ways, and it will be used there. We are only waiting until the lights are so perfected that they can be run easily and smoothly, and not be in danger of going out; and, also, we would like, if possible, to wait until we can get more work from the force we expend. Of course you all know that in any electric light, the arc light particularly, the amount of force expended bears no considerable relation to the amount given out in the form of light. Improvements are being made constantly in that direction.

Now any light can be seen in clear weather, but in a fog an electric light is not so well adapted as the ordinary light for the purpose, that is, if it be an arc light, because the greater portion of the rays are blue and violet. What we want in thick weather is yellow and red rays, rays of long wave length. If you take a red glass and put it in front of the ordinary light, as we sometimes do in our light-houses, it diminishes the illumination to about 40 per cent. of what it was before. If you put it in front of an arc light it diminishes it to about 10 per cent. of what it was before. So there is an enormous loss on that account. If, on the other hand, you take the incandescent light, you are no better off than before. You do not get greater results for the same area; or, if you do, it does not pay for the difference.

Now where there is a little haze in the atmosphere, or where it is a little thick, then you cannot see any light, and must depend upon sound. It was right in these two districts, more particularly in the first district, where the sound signals were first developed. The siren, as you all know, first started in America. Then the fog-signals have acted very eccentrically upon the coast of Maine, more so than anywhere else. There is a great field for science there. As Mr. Adams says, there are dead spaces.—A fog signal can be heard perhaps for a mile, then it will be dead for about a mile, and then away out fifteen or sometimes twenty miles to sea you can hear it again.

Now some ten or fifteen years ago Prof. Henry, then chairman of the Light-House Board, devised a theory on the subject, in regard to

the reflection from the surfaces of the little waves, and he explained every kind of phenomena. But the light-house engineer at that time, in his report, gave an account of his own which was characterized by the practical sense that he always showed on those subjects. He did'nt attempt too much, but what he did was right to the point. Then Prof. Tyndall, who was making experiments for the English Light-House Board, took up the gauntlet, and got up a theory about acoustic clouds, an excellent theory of what sound would do if it struck an acoustic cloud. There was a dead space in the sound of the fog-signal at White Head. But it happened afterwards that we had occasion to change the dwelling house there, and we put up one with a roof that reached nearly to the ground instead of presenting a broad reflecting surface, and the pilots now report that the dead space has disappeared.

Now that does not show that there is no use in trying, or that science has no relation to engineering at all. It was probably a case of the reflection of sound. It seems to me we can do a great deal by sounding boards and other apparatus, and we may make as many mistakes as any of them did, but we are going to see what we can do in the way of managing sound so as to get rid, as far as possible, of these dead spaces.

Where a Light-House is built out in the water a great many very interesting problems arise. This was the case at Minot's Ledge; and it is quite possible that right here in this district we may have a problem that will be more interesting from an engineering point of view than any other. I refer to the South Shoal, off Nantucket, about thirty miles off to sea. If a light were built there it would be the first light seen by vessels coming from Europe and going to New York. For a time there has been a light ship there. There was quite an interesting account of it in one of the monthly magazines about two years ago. That light-ship did very well as long as it lasted, but sometimes, instead of being thirty miles south of Nantucket, it would turn up in the West Indies. That light-ship has broken adrift from its moorings, and once it was found in the neighborhood of the Azores. It has masts and sails. Those sails are enough to keep it up head to the wind and keep it out of danger. The crew do not generally expect to get ashore more than once in five months. Recently that has been replaced by a steam light vessel, which, when it drifts out to sea, can come back again; and that will do very well indeed for the present. After a while we may need a light-house there.

During this past year there have been very few appropriations, and they have been very small, owing to the clutching of the political parties, and we had only about $50,000 this year, and that was for repairs. My predeccessor had given a great deal of attention to getting the lights in good order, and with that $50,000 we had this year we shall be able

to keep them in an excellent state of repair, much better than any of our private houses. But as you see from Mr. Adams account, the number of light-houses here is only about two-fifths measured along the shore line—about two-fifths as many to the mile as it is in France. Eventually we will have to have as many, and probably there will be some appropriations very soon. When any new work comes up, I hope I may have the opportunity of talking over with you any new problems that arise in their construction.

THE PRESIDENT:—I am sure we are all very much indebted both to Mr. Adams and to the Major for the very interesting paper and what it has been supplemented with; and as they know that we are Yankees, they are doubtless prepared to answer any questions. In starting what we hope may prove to be something of a discussion, the only suggestion that occurs to me at this time is that it seems to be apparent that scientific men must study the matter of the reflection of sound, and put the siren in some apparatus that may be as effective, if not as beautiful, as the lens that we have seen this afternoon, in which the light is placed. It seems as though sound should be directed in its course in as skillful a manner as that in which light is directed; and if we were to criticize the two kinds of signals it would be in that direction. The subject of light-house construction and the paper you have heard are before you. If any gentlemen would like to ask questions now is their opportunity.

I would like to ask the Major if any attempt has been made to carry out what he indicated; that is, the matter of reflecting sounds and throwing them on a horizontal plane.

MAJOR LIVERMORE:—Yes, there has, to a certain extent; but I want you to bear in mind that lighting is a matter of hundreds and perhaps thousands of years, whereas sound signals are all within our own day and generation. It is entirely a new departure, and a few years ago there were only one or two sound signals in the world. Now we have got to that condition where we feel the necessity for them, and we are working at it. There have been efforts made in that way, but there has been nothing like the time spent on it that there has been on lighting. We have tried a reflector in different ways, and we get good results sometimes.

THE PRESIDENT:—Evidently it is in something the condition of ventilation; that is, we build the apparatus first and then try whether it is going to work or not. In the first place, sound does not work like light. The light may be entirely utilized and all directed in a horizontal plane, while sound evidently goes where it pleases.

MAJOR LIVERMORE:—Yes; of course you cannot direct sound waves in straight lines, as you can light, because sound waves are too long; and you can hear round the corner while you cannot see round the cor-

ner. That is the great trouble we have had. I will say this, if you want to know seriously about some of these experiments. There was one fog signal in the neighborhood of some summer residences, and one of the summer residents,, who was quite an influential politician, asked the engineer in charge if he could not furnish these light keepers with barometers, so they could tell just how far off the fog reached, because sometimes they blew the fog-horn when it was perfectly clear off at his house.

Mr. J. C. Trautwine Jr.:—The remarks of Mr. Adams and of Major Livermore respecting the curious fact that the sound of a fog-horn is inaudible at certain moderate distances from its source but again becomes audible at greater distances, then, in turn, inaudible and audible again and so on—called up in my mind a picture of a series of alternate conical shells of sound and of silence, having their common axis in a vertical dropped from the fog-horn, their common apex in the horn itself, and their bases resting upon the sea; so that a person, upon leaving the vicinity of the fog-horn and proceeding sea-ward, would pass alternately into regions of sound and of silence.

This is merely another way of stating the case, as I understand it from these gentlemen, and must be a familiar figure to them. I mention it only because I trust it may suggest to them some easy method of enlightening us as to the cause of the phenomenon.

Major Livermore:—We are satisfied that it is due to wave interference, and that the reflection is not always from an acoustic cloud and not always from the tips of those little waves. Prof. Henry's theory was disproved afterwards practically. I did not want to go too deeply into the detail of our own business. Prof. Henry's theory was disproved from the fact that we got just exactly the same effect on a calm day when the sea was as smooth as glass as we did on a rough day. That knocked Prof. Henry's theory out. Then Prof. Tyndall's theory about acoustic clouds was set aside because it was found it did not correspond to the facts. Now all those things may have had a good deal to do with it, but they didn't work nearly as well as the barn.

Mr. Trautwine:—Where was the barn?

Major Livermore:—The barn was behind the signal. Of course you always take those things into consideration in selecting the site for a fog-signal. You always consider whether the sound would be likely to be thrown out in any one direction, but you do not attempt to calculate where all the waves would go.

Mr. Adams:—There is one part of the idea of Prof. Tyndall that has not been brought out, and that is that he considered that there might be what he called flocculence in the air, which might occur on the sunniest days, when there would be a non-homogeneity in the air, due to currents of various temperatures. If a stream of warm air was pass-

ing upwards between colder ones, the air there would not be homogeneous, and would be likely to have a refractive influence, on the sound, and disperse the waves of sound very much as ground glass disperses the rays of light; and probably that does have some definite effect. It is almost certain that when the air is not homogeneous the sound is not heard as well. But I do not think that that alone, as has been indicated by Major Livermore, accounts for all these dead spaces. I do not think any one of the reasons that have been given will account for them all. I think they all have their effects.

THE PRESIDENT:—I would like to ask the Major if there has ever been any attempt to use the Phonograph in any experiments in this line.

MAJOR LIVERMORE:—You know Prof. Henry used a membrane covered with sand that made beautiful little figures on it; and you could judge by that, if you were about a half a mile off from a siren like the one we have heard this afternoon, whether it was audible or not. You could also tell the shape of the figures it would make on this membrane. A phonograph would be an excellent thing, and some of the phonographic methods would be grand, without any question whatever. But in carrying out the experiments, if we did it on any extended scále, we would undoubtedly use a method which is common to the phonograph and the ear trumpet in the multiplying of sound; and other methods, such as are used in the telephone.

MR. ADAMS:—This use of sand upon the membrane, to which Major Livermore has referred, was used by Prof. Henry in attempting to decide which fog-signal gave the loudest sound. The persons present on the steamer, all hearing at the same time these various signals, could not agree which one was really the loudest, and they decided the question by means of this membrane and the sand. The fog-signal was the loudest which gave the greatest disturbance to the sand on the membrane.

MR. G. F. SWAIN:—There is one question that has not much to do with the subject that I thought I would like to ask Major Livermore, and that is with regard to the English Light-House Service. I have never been quite clear as to the relation of the Trinity House with the British Government.

MAJOR LIVERMORE:—The Trinity House takes a position that is similar to that of the Light-House Board here.

MR. SWAIN:—It is a Government Board is it?

MAJOR LIVERMORE:—Yes, I think now it is entirely under the Government. My impression is that it started as a sort of syndicate of contractors. They undertook it, and then finally the Government assumed control of it. But I am not sure about that. I think Mr. Adams could tell you about that better than I could.

MR. ADAMS:—I think that this Trinity House was very much like

the Board of Trade or the Board of Commerce. It has a connection with the Government very similar to the Bank of England, which is a private corporation and yet issues government bills.

MR. SWAIN:—And there are Government directors?

MR. ADAMS:—Yes, as I understand it. I may not be entirely correct. I think there are Government members of the Trinity House, but originally they were from the men of commerce and trade.*

THE PRESIDENT:—If there are no further questions I think that we may consider that this meeting has come to an end, and that we are certain that it has been one of the most successful of the season.

McGEE GRANT.—A MEMOIR.

BY THOMAS DOANE, COMMITTEE OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read Sept. 20, 1893.]

McGee Grant was a member of the Boston Society of Civil Engineers from March 24th, 1875.

Mr. Grant was the son of Thomas and Sylvia Grant, and was born in Copake, Columbia County, New York, December 28th, 1822. He was married in Charlestown, Mass., November 22nd, 1860, to Miss Maria J. F. Goold. They had no children.

After a busy professional life, he died in Somerville, Mass., on May 10th, 1892, and his place of burial was at Newburyport, Mass. About a year before his death he began to be afflicted with loss of sight, from which he could not be relieved. He gradually failed under this affliction, and for some two months before his death he was confined to his room.

The following is a concise list of the various engineering works upon which he spent his life and energies.

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*NOTE:—"Corporation of Trinity House, an Association of English Mariners,—from Elizabeth in 1573 received authority to erect beacons and other marks for guidance of navigators along the coasts of England. It is also recognized as an authority in the construction of vessels for the Royal Navy."—*Encyclopædia Britannica.*

"In 1836 an act of Parliament vested in the Trinity House the entire control of the Light-Houses of England and Walee, and gave it certain powers over the Irish and Scotch lights;" but "since 1854 the Trinity House has been subordinate to the Board of Trade, whose President is one of the Queen's Ministers." "The Elder Brethren, twenty-nine in number, comprise sixteen active members, including two officers of the Navy, and thirteen honorary members, all of whom are elected by the body as vacancies occur. The honorary members include his royal highness the Prince Wales, some of the ministers to the Crown, several members of the nobility and of Parliament."

"*European Light-House Systems.*" BY MAJOR GEORGE H. ELLIOT.

In Engineers office, City Square, Charlestown, Mass., from 1853 to 1864; being engaged two years on construction of Mystic Branch R. R.; two years on relocation and set of plans of Fitchburg R. R. and Branches; three years on Charlestown Water Works, locating, and in charge of construction of Reservoir, Pumping Station and pipe laying from Gate House at end of conduit, to Charlestown neck; balance of time on Horse R. R., city and job work; 1864, '65 and '66 on location and construction of Old Colony R. R., from Braintree to Dighton; also preliminary lines on Sugar River R. R., in New Hampshire; 1867 preliminary lines on Portland and Ogdenburg R. R., in Vermont and New Hampshire; 1868 location and construction Burlington and Missouri River R. R., from Afton to Missouri River, Iowa; 1869 and '70 location and construction of Alabama and Chattanooga R. R., from Chattanooga, Tenn. to Livingston, Ala.; 1871 city work in Somerville, Mass.; 1872 and '73 location and construction Old Colony R. R., from Wellfleet to Provincetown; 1874 city and job work in Somerville, Mass., 1875, '76 and '77 relocation and construction Troy and Greenfield R. R., from Hoosac Tunnel to Greenfield; 1878 construction Manchester and Keene R. R., from Harrisville to Keene, N. H., 1879 relocation and set of plans of Old Colony R. R., from Middleboro to Provincetown, Woods Holl and Branches in Rhode Island; 1880, '81, '82 and '83, location and construction Northern Pacific R. R., from Mandan, Dakota, to Yellowstone Park, Montana and preliminary line through Park; 1884 to 1887 preliminary lines Old Colony R. R., from Mattapan to South Framingham, laying track Chatham R. R., location of Massachusetts Central R. R., from Bondville to Chicopee, and job work in and about Somerville; 1888 in charge of building Elevator, Engine House and Canal Basin for Fitchburg R. R., at Rotterdam Junction, N. Y., also preliminary lines in Adirondack Mountains for Adirondack Railway Co., N. Y.

The writer of this notice was familiar with Mr. Grant and his work, while he was in and about Charlestown, while he was engaged upon the Old Colony R. R., and while he was upon the Troy and Greenfield R. R., and upon the Northern Pacific R. R.

He was an honest, straight forward, faithful and industrious worker, and modest and kind in all that he did. I have considered him especially capable in fitting railroad lines to the topography of the country, both to secure good alignment and to keep down cost of construction.

Mr. F. W. D. Holbrook, now of Seattle, Washington, knew Mr. Grant very well, and was associated with him on several railroads. He says of Mr. Grant, that "he was one of the reliable hard working Engineers who do the ordinary work of this country, and who receive but little compensation or thanks therefor. I always had high respect for him—and he was always pleasant."

MODERN GUN MAKING.

By Capt. W. H. Jaques, Bethlehem, Pa., before Western Society of Engineers.

[Read October 16, 1893.]

Mr. President, Gentlemen:—I have enjoyed Chicago's hospitality so often that when the Engineering Congress met, I thought I could come again to the progressive city of Chicago and listen to what its eminent Engineers had to say without being called upon to more than admire and enjoy. When a suggestion was made for me to present a paper to your Society, I replied with an eastern diplomacy, that was intended to give an indefiniteness carrying with it at least a winter's preparation. You may imagine my surprise, therefore when I received the following letter from your President:

Capt. W. H. Jaques,
care Bethlehem Iron Co., Bethlehem, Pa.

Esteemed Friend:—Enclosed you will find slip giving the proceedings of the last meeting of the Western Society of Engineers, and will kindly note paragraph which particularly interests you,—at least I hope it will,—and may I ask you to advise me, as soon as you can. the date on which it will be most convenient for you to give us your paper?

Your kind reply will oblige, yours truly,
(Signed.) Robert W. Hunt.
Pres., Western Society of Eng'rs.

The slip referred to was:

"Before introducing the business of the evening, the President called for a vote of the Society on the question of postponing the date of the October meeting to admit of the presentation of a paper by Mr, W. H. Jaques, for which it was impossible to arrange on the regular date."

There was nothing left for me to do but to recognize this masterly diplomatic stroke by placing myself at the Society's disposal for an early date in October.

Before making a gun, firing it, and showing its effect on armor and the remarkable resistance of the latter, I want to express my appreciation of this wonderful World's Columbian Exposition that has brought together so many eminent men representing every branch of Engineering.

When we stop to consider the financial and engineering responsibilities alone, we cannot but be amazed at the marvellous accomplishment. Recalling the safe Transportation to and from the Fair in one day of three-quarters of a million of people we are more than ever indebted to that department of the Exposition, so ably installed and conducted by Mr. Willard A. Smith and his assistants, which displays the means of such an accomplishment.

As I had the honor of being one of the judges of this department, I can personally testify to the excellence of its unique and comprehensive collection.

In effecting all this, there has not only been no sacrifice of grace and beauty of form; but, in addition to the fascinating panorama, there are individual productions as, for example, the Administration Building, (if but one bit of architecture be selected) even more beautiful at night, which are already famous for their artistic merit.

But perhaps, the crowning feature may be credited to the Engineers who provided the combination of seeing it all under the most attractive and valuable conditions, novelty of design, simplicity of construction and economy—the Ferris Wheel.

Another delightful episode of this Columbian Anniversary has been the Naval Review, which brought together an international fleet. The "Santa Maria" brought to our shore by Captain Concas, in a trip of the same duration as that of Columbus' original flagship; the "Viking Ship," in which Captain Anderson will sail down the Mississippi on his journey homeward; Great Britian's Cruiser "Blake," after which our 21 knot cruiser "New York" was fashioned; French Armorclad "Jean Bart;" German Cruiser "Kaiserin Augusta"; Italian Cruiser "Giovanni Bausan"; Russian Cruiser "Dimitri Donskoi"; Spanish Cruiser "Reina Regenta"; Brazilian Armored Cruiser "Aquidaban"; Argentine Republic Cruiser "Neuve de Julio"; and the Dutch Cruiser "Von Speigk"; —all joined to make memorable the 400th Anniversary of the discovery of Chicago—I mean America.

For convenience I will divide my paper to-night into two parts the first relating to the construction of the *built-up* gun, the other to that type now popularly known as *wire-wrapped.*

Both subjects are too extensive to have justice done them in a lecture of an hour and a half. I shall attempt, therefore, only a short, historical sketch.

As I have spoken upon the same subject before other institutions, Franklin Institute, Boston Institute of Technology, New York Naval Militia and American Society of Civil Engineers, I ask your indulgence to consider their publications as taking the place of the advance copies of papers usually distributed to their members by most scientific societies.

As I shall follow the methods employed by the Bethlehem Iron Company, I will ask you to spend a few moments at our works in South Bethlehem, Pennsylvania. This view represents them as they appeared in 1889. This one, as they now exist; the plant for the production of guns, armor, shafting and other heavy forgings being shown in the foreground.

In describing the construction of heavy ordnance I shall keep within

a period of ten years, since, with the exception of increasing the size of the parts and decreasing their number, there has been no radical change from the recommendations of the Gun Foundry Board which were confirmed by the Senate Ordnance Committees; and, although all the leading nations have been studiously searching for, and experimenting with, new types, we find ourselves to-day employing for service guns those recommended by these committees.

The decrease of the number of parts was a natural sequence of the development of the means in the United States for the certain production of these increased integers. This practice has continued until we have reached the type advocated by Mr. Gledhill, in 1886, in which the few cylindrical or conical parts that are used to make up the gun are assembled, after taper machining, under great hydraulic pressure, either alone or in combination with screwing and proper shrinkage.

During this period no great change in the composition of steel for guns has been accepted, although alloys containing manganese, chrome, tungsten, copper, nickel, aluminum, etc., have been suggested and tried, with the view of securing increased hardness to resist the erosion, or a greater elastic strength to control the pressures that have accompanied the higher velocities.

Nitro-compound powders have been developed and successful results are reported where the highest service velocities have been obtained with half of the charges of brown powder previously employed. The enduring qualities of these so-called smokeless powders are doubted by many artillerists, but I have recently had the pleasure of receiving a visit from Mr. Alexander Anderson, who for many years was associated with Professor Abel, at the Royal Laboratory, Woolwich Arsenal, England, and who is credited with having perfected and patented the well-known smokeless powders whose methods of production are now controlled by the Chillworth Company. Of the stability of this new powder he assures me there is no doubt.

Referring further to what has been accomplished in Great Britian with the new powders, Capt. Sir Andrew Noble, C. B., F. R. S., acting in conjunction with Sir Frederick Abel, F. R. S., has carried out exhaustive experiments to determine the stability and comparative values of these compounds of nitro-glycerine and gun-cotton and the modern brown powders.

In his latest experiments with 6 inch B. L. Rifles of various lengths he has secured enormous energies with 0.4 inch cordite, and found great regularity of burning, stability and freedom from detonation. Although its erosive power was slightly greater than that of "brown prismatic," the surface appeared to be pretty smoothly swept away, while the length of the surface eroded was much less. With very long gun, light projectile and high pressure, a velocity of 4,980 ft. sec.

was obtained. It seems, therefore, that cordite is the most promising of these so-called smokeless powders, although a product of the United States called the *Leonard* is now giving gratifying results. Many of the mixtures of this kind are very apt to deteriorate by keeping, and to become uncertain in action in hot climates, and experiments in this direction must always be very completely carried out before the final adoption of an explosive. One of the causes which has made gunpowder so successful an agent for the purposes of the artillerist, is that it is a mechanical mixture, not a definite chemical combination, and that it is practically impossible to detonate it."

Reports from France speak enthusiastically of the results that French chemists and artillerists have obtained.

Our own officials state that the macaroni form has been adopted and that repeated experiments have further demonstrated its stability and safety.

Duff Grant, in his lecture delivered before the United Service Club of New York, December 17, 1892, gave an interesting comparison of the qualities of the old and new powders. He is Secretary of the Smokeless Powder Company, of London, and as such presented the productions of his company in the most favorable light; but even he tells of the danger of most of the nitro types.

Longridge, in April, 1892, in his advocacy of a more powerful field gun than that in use in the British service, based his proposals on the use of Nobel powder, stating that although he possessed very limited information respecting cordite, he had reason to believe that there would not be any great difference in the results were cordite substituted for the Nobel powder. Yet in the same paper he thanks the "*new powders*" for the immense progress already realized and expected in ballistic power, but calls attention to their increased pressures, which he thinks the wire system of construction will be utilized to resist.

Speaking further of them, he says: "It is a common error to suppose that these powders are a new discovery: they have been known in substance for the last thirty or forty years. What is new, is the improvement in the means of controlling their rate of combustion, so as to regulate the development of the pressure and permit of their safe use in guns. It now remains to adapt the guns to the new powders, so as with safety to utilize their vastly superior force."

But even Longridge, with all his enthusiastic claim for the incontestable superiority of the new powder, calls attention to the danger to be guarded against from the very fact of its being a so much more powerful agent.

Many interesting and successful experiments have been made, each nation claiming for its own invention the greatest amount of usefulness and stability. Few military questions are discussed now with

more fervor than that of the advantages and disadvantages of these nitro-explosives. Their advocates say: *My* powders can be used by anybody without fear; but they generally add: The greatest care, however, must be employed in their use. To which last statement their opponents point as indicating a well-known existence of danger that must not be overlooked.

In adhering to the built-up system of forged steel as the best type of gun construction, it is not with a feeling that some other type may not take its place and perhaps be more successful, but because we know all about it, what it will do, the strength of every part and how to insure it.

If anyone had assured us twenty years ago that cars would be speeding along rails at the rate of thirty miles an hour without horse or steam or cable power, simply by a force transmitted through wires; that we could talk over a wire for a distance of 1,000 miles with greater ease and distinctness than through the ordinary speaking tube; that aluminum could be bought for fifty cents a pound; that colors could be photographed; that photograph-telegraphy would be accomplished: we would have received his statements with great incredulity and would have listened to such suggestions with even less faith, if it were possible, than we now receive the prediction of Lieutenant Totten in regard to the destruction of the world; or, if we could have accepted them, would have regarded our informant as possessing miraculous foresight.

Therefore, while I accept the built-up forged steel gun as the best because I know how it can be made a perfect machine, and because I can recommend its being put into service without fear of its doing more harm to its friends than to its enemies, I have no desire to discourage the enthusiastic supporters of other types, for they may succeed as others have done before them, and the built-up forged steel, high power, breech-loading gun may be as permanently superseded as iron has been supplanted and replaced by steel.

Instead of suggesting designs for revolutionizing the present accepted type, I will proceed with the details of its manufacture.

You are all familiar with the production of the pig in the blast furnace, the parts, method of filling and blowing in, action and operation of the furnace and its accessories.

As the American furnaces have jumped to the front in the production of pig iron, it may be interesting to recall the dimensions of one of the largest. It was built in 1885-86: has a total height of 80 feet; diameter of hearth, 11 feet; diameter of bosh, 23 feet; the bell is 12 feet in diameter, and the stock line 16 feet; the cubical capacity is 19,800 feet; it has seven tuyeres of 6-inch diameter. The blast was used at a temperature of 1,200°, entering the tuyeres at a pressure of from nine to

ten pounds. The highest monthly output was 12,706 gross tons, or an average of nearly 410 tons per day.

Although Krupp uses the crucible process almost exclusively and Russia employs it largely, most of the gun steel, and all of it in the United States, is made by the open hearth process, the metal being melted in *open hearth* instead of in closed pots or crucibles. Steel made by other processes than the open hearth and crucible has shown physical characteristics equal to and in some cases more remarkable than those which fulfill the present requirements; but when such steels were used for gun construction it was found that they were not adapted to the purpose.

There are many forms of the open hearth furnace, differing in arrangement of regenerators, valves, shape of hearth and sloop of roof, but their general construction will be understood from the accompanying view of a Siemens regenerative gas furnace.

Bethlehem has four open-hearth melting furnaces, of the respective capacities of fifteen, thirteen, and two forty tons.

After the sole or bottom of refractory sand has been made and the hearth has been brought to a full heat, the raw materials, iron ore, pig iron, wrought-iron blooms, and steel scrap are put in through the doorways, generally in a solid state. As soon as the whole charge has been fully melted a series of tests is begun, which usually consists in taking samples in small ladles and casting them in small test ingots. These are cooled and broken and by the changing indication of the fracture and carbon determinations, as the process advances, the exact condition of the bath is obtained.

The reduction of the carbon is continued until it stands at the required percentage, when the bath is recarburized, by the introduction of a quantity of preheated spiegel or ferro-manganese, after which the metal is stirred and the contents of the furnace tapped into a ladle.

The sizes of the ladles are governed by the capacity of the furnaces and the class of work for which the steel is to be used. Of heavy iron construction, they are lined with a refractory mixture and pierced in two places in the bottom for the insertion of fire-brick nozzles, through which the metal runs into the moulds. Into these nozzles clay-plumbago stoppers are fitted and attached to heavy rods which extend upward and out over the side of the ladle to the levers or other attachments provided for lifting and controlling them.

The ladle is then transferred by rail to the fluid compression plant where the steel is compressed or run into the moulds for which the metal has been intended.

The moulds are of steel, iron, brick, or sand, and are of dimensions and shapes suited to the purpose for which the ingot or casting is to be used.

The Whitworth system of fluid compression consists in compressing the liquid metal in a mould immediately after pouring. The moulds are tapered cylinders made of steel and lined with refractory material. As soon as the mould is filled it is moved under the fixed head of the press and the pressure applied.

As soon as the ingot has cooled and contracted sufficiently, the mould is removed by the crane, and the ingot is lifted out of the casting-pit and taken to the heating furnace to be raised to the forging temperature.

These heating furnaces are of the general Siemens regenerative type, with large doors in front and rear, operated by hydraulic power and with spacious heating chambers to admit the largest work. When the ingot or block is raised to the needful temperature it is removed from the furnace and put under the hydraulic forging press to be shaped.

This press consists of a massive head and bottom secured by four forged steel columns held together by nuts. The head carries the hydraulic cylinder and ram with which the work is done upon the piece to be forged as it rests upon the anvil. The piece upon the anvil in the view before you is a hollow forging, the hole in the block having been bored or punched previous to putting it into the heating furnace. The press is fitted with cranes and other mechanical contrivances for the handling of the forging while it is being shaped.

The operations of drawing out a tube and enlarging a hoop by this method are represented in the following sketches. Into the heated hollow ingot a steel mandrel is inserted and both are placed between suitable dies fitted to the ram and anvil. As repeated pressures are given, the ingot and mandrel are turned round into fresh positions, and, as the metal cannot flow except in the direction of the length, the tube is reduced to the required diameter and drawn out to the requisite length.

This view represents a hollow cylinder weighing 28,250 lbs.; 44″ exterior diameter; 60″ long, with a hole 14½″ diameter.

It is represented in the left of the two right hand figures before forging, and was drawn down in one heat to a hollow cylinder 160″ long; 30″ exterior diameter, with the hole reduced to 14″, as shown in the right hand sketch.

The following heavy forgings were drawn out from bored fluid compressed ingots in the same manner.

Tube for 13″ Navy B. L. Rifle, smooth forged, 38′ 5″ long, 25½″ diameter, 12″ hole; weight 59,000 lbs. (26.3 tons). Jacket for 13″ Navy B.L. Rifle, smooth forged, 17′ ½″ long, 38¼″ in diameter; 23¾″ hole; weight 56,800 lbs. (25.4 tons). Shaft for the Ferris wheel, partially forged. The ingot from which it was made was 197″ long, 54″ diameter and weighed 120,500 lbs. A 16″ hole was bored in it before forging. Fin-

ished dimensions of shaft 45′×32″×16″ bore; weight, 89,320 lbs.

The two center figures represent the operation of drawing out a solid ingot (which before forging was 92″ long and 42″ diameter) in one heat to the shape represented here in the right hand one. In this heat half of it has been drawn into a forging 20″ in diameter; if the remaining portion is to be reduced to the same size, that not reduced will be reheated and drawn down in the same manner.

The two figures on the left represent the result of the operation of enlarging a hoop, which is shown in the upper figure before forging, and in the lower with the shape and dimensions which have been given to it during the extension.

This enlargement is produced by supporting the mandrel at both ends, leaving the hoop without any bottom support during the forging, which operation gradually increases the diameter and reduces the thickness of the walls without materially increasing its length.

These hoops were shaped in the same way, as was also this trunnion band.

These trunnion bands (which will no doubt soon be replaced by other means of securing the gun to the carriage) and solid forged cranks are very difficult forgings to make, but Bethlehem has had remarkable success with them.

The forgings being finished, they are then taken to the machine shop, where, in lathes illustrated by the following views, they are rough-turned and bored to their rough dimensions.

The forging is centered between the adjustable headstock and the chuck, which is fitted with steel adjustable jaws. As the forging is turned in the lathe the tools fitted to the adjustable tool-holders in their carriages machine it to the required dimensions, the tools being fed and the carriages traversed by suitable power and gearing. The number of tools employed (four in the lathe before you) depends upon the power of the machine and the methods of the manufacturer.

In boring, one end of the forging is attached to the chuck and centered in rests, and as the forging revolves, the tool at the end of the boring bar is fed as required.

When rough-bored and turned, the forging is taken to the tempering furnace, raised to the desired temperature, dipped into that liquid which is considered best to secure the requisite temper, and returned to the machine shop for the taking out of the specimens, the physical tests and appearance of which are to govern the acceptance or rejection of the piece they represent.

Authorities differ as to the value of oil hardening, but universally agree as to the benefits of annealing. Both are necessary to secure a reliable, uniform product. All gun forgings should be carefully annealed in order to bring to a normal condition any molecules or par-

ticles which may have been distributed by unequal cooling or working. Any form of heating furnace can be adapted for this operation, but those especially designed for the use and control of gas are to be preferred.

The specimens used by the Navy Department are of the type and dimensions here represented, while those for the army are the ones that you now see before you.

The forgings that go to make up the gun, having been accepted by the inspectors, are sent to the gun factory for assembling and finishing.

The Bethlehem Company has contracted to furnish the War Department with 100 high-power breech-loading guns of eight-inch, ten-inch and twelve-inch calibre, finished complete, its gun factory is now being rapidly equipped with the special machinery needed for their fabrication, and work on the eight-inch calibres has been commenced.

The interesting view now before you represents the interior of the principal gun shop of the Washington gun factory. The machines are arranged across the shop and are served by two travelling cranes of twenty-five and 100-ton capacity. The turning and boring lathes employed for finishing are similar in construction to those used in the rough work, but are not required to be so powerful. In the final machine finishing fewer tools are used.

In the first two machines of the view before you the operation of boring is being performed, the bit being attached to a long, strong bar, which is fed into the revolving tube or hoop.

Peculiarly-shaped bits, called "packed-bits" and "hog-bits," are employed for this work.

The next operation, after the parts are reduced to their finished sizes, is the assemblage. In this view we have the tube and jacket represented before assemblage, while the lower figure represents the parts as assembled.

The operation of jacketing a gun is shown in the two following views. The tube is secured in a vertical position in a large pit, and the jacket, raised to its shrinkage temperature in a hot-air furnace, is lifted from the furnace by the travelling crane and lowered to its proper place upon its tube. Water circulating through the interior of the tube and sprayed upon the lower end of the jacket governs the cooling to secure the proper shrinkage.

The view before you now is a very interesting one, showing jackets for the four, five, six, eight, ten and twelve-inch navy guns, ready for insertion in the heating furnace for shrinkage upon their respective tubes.

The hoops are shrunk on in a similar way, although much of this work in some factories is done in the lathe, the gun being then in a horizontal position.

The effective power of shrinkage is well illustrated in the accompanying view, a reproduction of an experiment made many years ago at Sir Joseph Whitworth's works in England, to show its effect and value.

A ring of mild, fluid-compressed steel, 30″ exterior diameter and 30″ long, was heated and shrunk on to a plug 18″ diameter and 16″ long, having a six-inch hole bored through its centre, the plug being turned up larger than the diameter of the ring by the proper shrinkage allowance. When cold, the plug was forced out by hydraulic pressure and it was found that it required a force of 3,000 tons to separate the two pieces.

Directly connected with the subject of shrinkage is the problem of the value of *internal stresses*.

Rodman is credited by Kalakoutsky with the explanation of their cause and importance and by Birnie for the exposition of the principle of initial tension in hooped guns, and to giving to the several layers of hoops such a shrinkage as would cause each to offer its full strength in resisting the action of an interior presssure calculated to rupture the gun. But Rodman applied them only in the foundry. Both, however, agree that we are indebted to Lame for the *origin* of the principles. Further, we owe many thanks to the late General Kalakoutsky of the Russian Artillery, and to Captain Crozier of the United States Ordnance Department, for their independent researches, which determined a numerical value for these stresses and pointed out how they could be converted from injurious into beneficial quantities.

The numerical values, evolved from the natural stresses, are employed to determine the magnitude of the stresses mechanically put into built-up cylinders. General Kalakoutsky devoted nearly twenty years of his life, from 1871 to 1889, the date of his death, to the consideration of these important questions of the law of the distribution of these stresses under the conditions of manufacture. He defined internal stresses as those which exist within the mass of any body when it appears to be in a state of repose or not under the influence of external forces.

The formulæ and tables followed in the regulation and preparation of the required shrinkages are the result of long years of research, study and experiment, and I know of no treatise on the subject which defines so simply and definitely the injuries and benefits of internal stresses as a work published in 1888, entitled: *Investigations into the Internal Stresses in Cast Iron and Steel*, written by the late General Nicholas Kalakoutsky, of the Imperial Russian Artillery.

A long list of experiments has not only supplied us with a vast amount of valuable mechanical and metallurgical data, but has given us additional assurance of the strength and endurance of the built-up

forged steel gun, as far as the material and construction are concerned.

There is another question, however, in connection with gun construction, which has not yet been satisfactorily solved, a solution of which may not be so easily attained; that is, how to prevent the erosion of the bore by powder products. This wearing of the barrel is at the present time a cause of the greatest anxiety to ordnance engineers and gun makers. Its disastrous effects in ordnance where such enormous powder charges are employed have no doubt greatly influenced some artillerists against the largest calibres, whose racking and smashing powers must be employed to destroy the heaviest armor.

If we do not change the propelling agent I believe we must look to the amount of work put upon the metal and its treatment rather than to the chemistry alone of the metal for the determining agents that will prevent or reduce the amount of erosion: and that the solution of the problem will be found in the mechanical field. This difficulty will probably be best surmounted by carbonizing the bore, which should be highly polished or hardened by mechanical mandrelling, in order to secure the smoothness needed to prevent scoring by powder products. The employment, therefore, of any alloy or of any mechanical work that will aid in securing this highly hardened smoothness, without reducing the requisite elastic strength, will greatly assist the solution of this difficult problem. These results cannot be obtained, however, by any sacrifice of attention to the chemistry of gun steel.

If erosion is mainly due to the chemical action of the powder gases and deposits that some powders leave, the powder maker, by changing the mechanical or chemical composition of his products or substituting some other propelling agent, may pass the mechanic in his search for the means of rendering his gun barrel impervious to the destructive action of powder just as the manufacturers of slow-burning powder outstripped the designers of accelerating guns in securing high velocities.

If we accept the new powders we may have to sacrifice the excellent ballistic results that the erosive powders have given, but if the mechanic succeeds, any kind of powder can probably be used.

If erosion is due to high pressures and temperatures the use of the stronger powders would increase erosion in the proposed short guns; but if it is due to the mechanical work of the non-gaseous (liquid and solid) residue, these new powders, if they can be made reliable, will be a boon.

After the final-finish-turning and boring has been accomplished the gun is chambered, the chamber being of a diameter greater than that of the bore, and the gun is put into the rifling machine to be rifled. The rifling head fitted as here represented, and the rifling is effected usually

during the withdrawal of the head by the bar to which it is attached. The number of cutters on the rifling head varies in different machines and the pitch of the rifling is governed by the guide bar as represented in this view or by gearing.

The threading and slotting are done by what is usually called a threading and slotting machine, which carries a tool in an adjustable holder that screws the thread or is employed as a slotter to remove those segments of the thread which allow the entrance of the interrupted screw of the breech plug, the gun being carefully centred in centring rests.

This view shows on a larger scale the operation of cutting the slot ways.

The breech plug, with its mushroom or other gas check, and the various devices for opening, closing, latching and firing, are then fitted, the gun is sighted and carefully examined, and we have the finished gun.

The present view represents a twelve-inch navy gun fitted to a proof carriage, showing the method of securing it to the slides, its breech mechanism open and a telescopic ram for loading attached to the carriage.

Of the two systems of breech-loading in general use—the American-French interrupted screw and what is now familiarly known as the Krupp wedge—the former is used by both branches of our military service.

While differing in details, the general operation is to unscrew the plug or breech screw, withdraw it, land and latch it on the tray, carrier or bracket (as this part is variously called,) swing the tray on its hinge pin to one side and catch and hold it there during the operation of inserting the projectile and powder charge.

This view shows the mechanism used by the Navy for the ten-inch and twelve-inch guns, when closed.

This view the same when the breech is open.

The apparatus employed by the Army is composed of a greater number of parts and is more complicated; but it works well and has a peculiar double-threaded shaft, by which increased power and speed are obtained for operating the breech-block.

Of the many hundreds of devices that have been proposed for the closing and gas checking of breech-loading ordnance, the most effective at the present time are the Canet-Whitworth breech mechanisms and de Bange gas check. Their chief advantages are strength, simplicity, effective gas checking and positive discharge of cartridge case when employing fixed ammunition. The lighter ones, although applicable to the heavier guns, are employed principally for rapid fire guns.

For calibres up to and including eight-inch, the breech plug is dis-

engaged and withdrawn by a simple rotary single movement of a lever in a horizontal direction and again entered and engaged by a similar movement in the reverse direction.

For the heavier guns, where hand power is employed instead of pneumatic or hydraulic power, the breech plug, carrier or tray and fittings are controlled, disengaged and withdrawn by a continuous rotation of a crank in one direction and the reverse movement governed by a similar rotation in the opposite direction.

The re-cocking is performed by levers and sliding bars during the operation of opening the breech, and safety guards are automatically adjusted in the closing, which prevents any possibility of the gun being fired before the breech is perfectly closed. Spring catches are fitted to control the motion of the various parts while the breech is open.

In the Canet system when the shaft J is rotated, motion is communicated through a worm at its end to the worm-wheel H, which is fitted and gives motion to the screw-shaft F supported at its extremities by suitable bearings screwed to the breech of the gun. The collar C and toothed-wheel E, prevented from rotating by a projection working in a groove in the tray, move along the screw-shaft F, rotating the breech plug until it is disengaged from the interrupted screw threads in the breech of the gun, when their translatory movement being stopped they are released and the wheel is left free to engage the screw thread of the breech plug, and by its revolution withdraw the block or plug from the breech, landing and locking it upon the tray which is then swung upon its axis to, and locked in, the loading position. To close the breech the operations just described are reversed. All of these operations are done by a continuous rotation in the direction requisite for opening or closing the breech.

The de Bange gas check proper is a plastic ring composed of sixty-five per cent. of amianthus (an earth or mountain flax, similar to asbestos) and thirty-five per cent. of tallow, contained in a canvas covering. It fits snugly around the mushroom-shaped stem which is inserted in the axis of the breech block. Zinc, copper or steel discs protect the plastic pad and keep it within its proper limits. The asbestos, being a mineral, and not combustible, retains the tallow and prevents the mixture from becoming fluid. The tallow being soft and greasy, yields easily to the pressure and takes the form of its casting; oozing slightly through the canvas cover it acts also as a lubricant.

When the gun is fired, the pressure upon the movable head is transmitted to the gas check, which is forced against the side of the chamber, effecting perfect obturation.

Although *not* the case in all constructions and particularly in the French, the breech screw or plug should engage in the jacket and not in the tube.

Canet suggests that the thread be interrupted by cutting away helical segments instead of straight longitudinal ones, which is the usual method. This would make the mechanism not quite so simple to manufacture as the other, but its advantages may compensate for that since the thrust is more uniformily distributed over the screwed portion of the jacket. I know, however, of no accident ever having occurred which was due to the usual type of interrupted screw.

Two American breech mechanisms, that are receiving attention abroad as well as at home, are the Seabury and Gerdon. Both may be applied to the heavy calibres.

These views, showing the breech open and closed, were taken from a six pounder rapid fire gun fitted with the Seabury mechanism, now at the Sandy Hook Proving Ground awaiting test.

Although there is no necessary limit in its application to either large or small calibres, for guns of five inches and upwards, *this* design, will probably be preferred, gearing being substituted for the hand lever in the largest sizes.

The Gerdon system of breech mechanism, is a combination of the interrupted screw with the sliding wedge, or a contrivance composed of what Mr. Gerdon considers the best elements of those two well-known and prolifically modified devices. He claims to reduce the three motions of rotation and translation of the French system to one of each retaining the superior de Bange gas check; but as these three motions have been converted into a continuous one in the Canet and Seabury systems, the test of the Gerdon device that is now being made in a field gun may not prove the combination to be as simple and effective as the latest designs of the French type.

A variety of materials has been proposed and advocated for heavy gun construction. but *steel* advocated by Whitworth and Krupp as early as 1860 and still employed by them has vanquished all others in the race and seems likely to be retained for as long a period to come.

While the Whitworth plant in only *indirectly* represented at this Exposition by the products of the fluid compression and hydraulic forging presses purchased of that firm by Bethlehem, Krupp has installed in a separate pavilion one of the most unique and interesting collections of preparatory and finished war material ever exhibited.

It would be impossible to praise too highly the enterprise with which the risk of transportation and difficulties of installation of this remarkable collection of products were met; the masterly conception and accomplishment and the liberality with which it has been effected. It is a veritable exposition in itself.

Both branches of our Government use almost exclusively, for their *heavy* guns, fluid compressed, hydraulic forged steel, and. as they have become assured of the soundness of the material when produced in

larger masses, have decreased the number of parts of the guns. For example, those of the eight-inch gun, numbering ten in 1887, to three parts in 1892.

The danger of using material that has not been adequately worked is well illustrated in this view of a section of the steel shaft made for the U. S. Despatch Boat "Dolphin" by the Nashua Company under a small hammer.

The value of fluid compression will perhaps be better understood by a study of the following views showing sections of an ingot cast in the usual way and one compressed when in a liquid state. This experiment was made at the Aboukoff Steel Works in Russia by Admiral Kolokoltzoff.

The increasing use of nickel in steel suggests a few words concerning this element, particularly as it is about to make its debut in a large calibre service gun (a thirty-five calibre eight-inch B. L. R.,) the forgings for which have been made by the Bethlehem Iron Company.

In this connection it is most seriously to be regretted that circumstances of a discouraging character should have intervened to prevent Mr. Riley's continuing the excellent metallurgical work he so happily and ably commenced in connection with the alloys of nickel and steel, particularly since the publication of his lecture to the Iron and Steel Institute, May 4, 1889, so many of his views have been proved by further experiment and practice.

Bethlehem's part in this work is so well known by the practical results she has obtained, the gun forgings and other products supplied and the superior resistance of her armor, that I need make no detailed statement here of our accomplishments. Further, they have already been referred to by the chiefs of the Bureaus of Steam Engineering and Ordnance in their last annual reports.

As you will no doubt recall, Riley, Dick and Packer commenced their experiments with samples of French crucible nickel steel containing three per cent., five per cent. and twenty-five per cent. of nickel; were subsequently assured by personal investigation that the desired products could be obtained with certainty, not only in the crucible but with perfect control in the open hearth, and that nearly all the nickel would be found in the steel. Riley, in the lecture referred to, described the action of the steel in the mould, its appearance, value of scrap and the care and temperatures required to work it. He made a sufficient number of tests to show the marked increase of tensile strength and elastic limit produced by certain increments of nickel without impairing the elongation or contraction of area to any noticeable extent. He pointed out the effects of a variation of the proportions of carbon and manganese with the same percentage of nickel, the point where the increment of nickel changed its hardening influence to one of softening,

ductilizing, its neutralizing effect upon carbon, the difficulties of machining, and crowned his report by giving due credit to the patentee, French steel makers, his assistants and the authorities.

Together with other conclusions, he said: "I am glad to be able to state that before the region of extreme difficulty of machining is reached we have qualities of nickel-steel available which will be of the utmost value for a very large number of purposes."

Comparing ordinary steel with nickel-steel he adds: "I think there will be no hesitation in deciding that there will be a very great advantage gained by the use of the latter—advantage either in reduction of scantling or in increased strength and ductility.

"In the very important matter of corrodibility, it is with the greatest satisfaction I can state that the steels rich in nickel are practicably non-corrodible, and that those poor in nickel are much better than other steels in this respect. Some samples of the richer nickel-steels which have been lying exposed to the atmosphere for several weeks will show an untarnished fracture."

These experiments to test the non-corrodible qualities of the various percentages of nickel-steel, it will be remembered, were made in connection with Abel's corrosive liquid and hydrochloric acid water.

I have cited Riley's conclusions to show how accurately they have been verified by the results since obtained, which give abundant testimony of the care and faithfulness with which his experiments were made.

Mr. Hall, of Sheffield, claims to have made the first nickel-steel gun, which instrument is reported to have burst at the first round, the rupture being due to the absence of suitable transverse strength. Whether this was due to the poor steel, poor construction, or the presence of nickel was not stated.

Many other nickel-steel guns have been experimented with, but comparative tests of two three-and-a-half-inch field guns, one made of ordinary Krupp steel, and the other of nickel-steel, appear to be the first trials of much importance that have been given publicity.

Each gun was loaded with shell containing 170 grammes of picric acid, the centre of the shell in each case being 300 millimetres from the muzzle.

When the shells were exploded, the crucible steel gun burst into many pieces, while the nickel-steel gun remained entire, showing an increase of the bore of 7·4 millimetres at the site of the projectile, but no cracks anywhere.

The trial was continued with another shell containing 180 grammes of picric acid. Its explosion caused an enlargement of 9·50 millimetres and a longitudinal crack 80 millimetres long. No particle of metal was detached from the gun.

In reference to the supply of nickel for guns, armor and the great variety of the industrial arts, a perusal of the able report of Mr. Archibald Blue, Director of the Bureau of Mines, Ontario, will satisfy you all that the ore is to be found in abundance nearer than New Caledonia, money and plant being important requisites.

In connection with gun construction, it may be interesting to you to recall some of the earlier breech-loading guns, in order that you may recognize the progress that has been made. The original Armstrong gun contains practically nothing that has been retained, while the Whitworth gun here shown, made in four parts, contains, with the exception of the mechanical shape of its bore, much that is in use today; it was made of steel, of few parts, and had great strength and high power. It is true it is a later design than the original Armstrong gun, but the earliest Whitworth guns were made of steel, were strong, and had a very efficient wedge for closing the breech.

Passing from the Armstrong gun of 1861 to another of that famous establishment's productions thirty years later, we have before us the 110-ton breech-loading rifle which, with 960 pounds of brown prismatic powder, costing $400, discharges a steel projectile weighing 1,800 pounds, valued at $600; muzzle velocity, 2,087 foot-seconds: muzzle energy, 54,390 foot-tons; penetration of wrought iron at muzzle, 34·2 inches, at 2,000 yards, 30·1 inches.

The British 110-ton guns, about which there has been so much discussion, are not only faulty in construction, but are composed of too many pieces, the chase hoops particularly being too numerous and short to be of any use in supplying the longitudinal support which the long tube requires. The original design has undergone two marked changes, substituting longer hoops, but even these were not of sufficient proportions to entirely remedy the defects of the separation of the remaining short hoops on the upper side caused by the drooping of the muzzle.

The gun, even as it now exists, should not be imitated, and will not be by such gun factors as Whitworth and Bethlehem, who possess the powerful appliances requisite for shaping, treating and assembling the few heavy parts that should make up guns, even of such heavy calibres.

Whitworth's new thirty-five calibre twelve-inch, fifty-ton breech loaders for the British War Office, composed of three pieces only, are but a precursor of as simple and strong a design for the heavier calibres.

Another design combining few parts, simple construction, strength, separation of the tranverse and longitudinal strains, in which the tube can be turned in case any portion of it becomes badly eroded, easily transported in parts, and readily taken apart if any injured parts re-

quire to be replaced, is the de Brynk gun, the suggestion of a Russian artillery officer. A number of these guns have already been put into service. This figure is the gun assembled.

This reproduction will give you an idea of the progress made between the years 1837 and 1887. Both guns are drawn to scale and the upper figure represents the largest gun employed in the British Navy in 1837, the lower the 111-ton B. L. Rifle of Her Majesty's Barbette Battle Ship "Benbow."

I desire to especially emphasize the causes of the mishaps to the British 110½-ton guns, because their failure does not convey to my mind any reflection upon the usefulness of such large calibres, for it is quite as simple for the steel works I have just named to construct a sound 110 ton gun as it is for smaller establishments to make a one-pounder; and there can be no doubt that the more powerful the guns of a battleship are the more formidable an enemy she will be.

I deem the failures mechanical only, and if the guns are constructed in a manner equal to many of the modern marine engines that have been built in Great Britain, they will be equally efficient and serviceable.

The efficient service of these guns must not be compared directly with the number of rounds that can be fired from smaller calibres, and the weight of metal thus employed, but from the effective amount of destructive work that can be got out of them, particularly their power to demolish the hard armor of chilled iron and case-hardened steel now so successfully manufactured.

The United States is not the only nation engaged in successfully producing hard armor, nor is the method employed by Mr. Harvey, although thus far the most successful, the only one that the gun has to meet.

The general success and probable general acceptance for a period, of hard armor, would seem to emphasize the opinion I have so often expressed that Great Britian's reduction of fifty per cent. in the maximum weight of her ordnance was too radical and not justified by the circumstances attending the failures that influenced the change.

The tendency to substitute for the larger armament an increased number of guns of reduced calibre, notably of the rapid-fire class, will no doubt soon meet with a reaction, because of the loss of that powerful element of destruction, the shattering power so necessary in combat with heavily armored ships. A mixed battery of large and small guns is no doubt the most useful compromise, for what is a ship to-day other than a compromise—in fact, a combination of comprises?

If the hard faced armor cannot be perforated, it must be shattered to disintegration. The trials of 1886 at Spezzia with Gruson chilled iron armor are interesting in this connection.

The proving-ground in the bay of Castagna.

The pontoon on which the 100-ton gun was mounted.

The distinguished party awaiting the shots.

The plate to be tested.

The target ready.

The first shot.

The target after the first shot.

The plate after the first shot.

The plate after the second shot.

The third shot.

The plate after the third shot.

Of other systems of gun construction and other material than forged steel, recommended for trial within the last few years, may be mentioned the Woodbridge wire-wound guns, of ten-inch calibre (employing longitudinal bars and soldered wire) for the Army, and six-inch for the Navy; the Crozier ten-inch wire-wound gun (jacketed and hooped with steel castings;) the five-inch Brown segmental tube wire gun; the Haskell multicharge gun; the twelve-inch cast iron mortar, and two six-inch steel cast guns.

Three of these have been tested and failed, viz: the two steel cast guns and the twelve-inch cast-iron mortar. In December, 1888, the Bessemer steel cast gun went to pieces at the first round with a full charge, doing considerable damage to the proving ground. In February, 1889, the open-hearth steel gun was tested; the report of the trials stated that although the gun escaped rupture the test demonstrated, as calculated, that the service pressure, while less than fifteen tons to the square inch, was too great for the elastic limit of the metal and that the permanent enlargement of the bore was greater than could be admitted in a gun issued to service.

The twelve-inch cast-iron mortar burst explosively and violently in October 1889, at the twentieth round, and a long-fought battle for cast iron was finally decided.

Some of you will recall that a gun of the Woodbridge type burst a few years ago; also that a Haskell gun failed and although slow-burning powder has in a much simpler way supplied what the Lyman-Haskell type was designed to accomplish, Congress authorized the construction of another gun which is now being built from designs possessing a little less architectural beauty than the one now before you, but quite as unmechanical.

For mortars, the forged built-up rifled type of steel construction is also generally accepted and greatly increased accuracy and range are obtained.

Viewed from the point of their destructive power, if successful, the pneumatic and other types designed for throwing high explosives

should be embraced in this paper, but they are not yet assigned a place among high-power breech-loading rifles, although many of them have been undergoing trial for years with varying success and failure.

Bott, Chamberlain, Dudley, Ericsson, Gathmann, Giffard, Graydon, Haskell, Justin, Lassoe, Mefford, Rapieff, Reynolds, Zalinski and others have had their inventions tested more or less extensively, employing air or powder for transmitting energy to the projectile. Bott and Chamberlain, I think, are the only ones who place the motive-power in the projectile itself. It is said that Bott fills the rear of his shell with compressed air instead of introducing the air in the gun; while Chamberlain uses electricity and hydrogen in either the projectile or gun. Giffard employs liquid carbonic acid instead of powder.

Of all these types, the Ericsson-Lassoe (submarine) now being tested by the Navy Department on board the "Destroyer" Chamber containing gun, projectiles, air compressor, reservoir and fittings—Lassoe projectile—and the Rapieff-Zalinski, with its modifications (aerial) have given the greatest promise, and will, no doubt, be introduced into general service.

Rapid-fire guns have already gone beyond their own domain and encroached upon the field of heavy ordnance, having been successfully carried to calibres a little above six inches.

The Schneider 4.7 inch on exhibition in Transportation Building is a splendid example of this type.

To fully describe the many designs for which novelty and value are claimed would require many days, and the differences between them would be of little interest to others than the inventors and patent attorneys.

In regard to the development of our industries for the supply of heavy ordnance a most satisfactory account can be rendered.

In 1886, we had practically nothing. To-day steel for guns of any calibre can be supplied by the private steel industries of the nation, and two splendid gun factories have been built and equipped where the forgings can be quickly machined and assembled, and the guns rapidly fitted for service. These two gun factories will soon be supplemented with a third at Bethlehem.

Not only all this has been accomplished, but from the great establishment at Bethlehem alone (built up and equipped without any financial aid from the Government,) the Government has received over 400 sets of gun forgings (including those of thirteen-inch calibre) and armor plates of ten and one-half, fourteen and seventeen inches in thickness, whose resistance has astonished the world; while the Navy Department and our splendid shipyards depend almost solely upon it for shafting and other heavy forgings.

There are many to whom much credit is due for this splendid pro-

gress, many spokes of the wheel that is running so smoothly and successfully now, but most credit seems due to the organization of and encouragement given by Secretaries Chandler and Lincoln to the Gun Foundry Board appointed by President Arthur in 1883. This Board, after familiarizing itself with the situation at home, gleaned from the old world all that was needed to frame recommendations adapted to our own resources and requirements. Its suggestions were so comprehensive that we find the policies of the two departments to-day encompassed by them.

This report and the subsequent legislation based thereon marked as distinct an era in the restoration of our prestige as producers of war material as the Registry Bill passed last year bids fair to record in the rehabilitation of our merchant marine.

To show the effect of modern steel projectiles, when fired at high velocities against steel plates, I have prepared the following views of the results of the test of an eleven-and-one-half-inch Bethlehem plate.

These results, however, have been so greatly surpassed by succeeding experimental and service plates which Bethlehem has delivered to the Government, that they are presented only for the purpose of showing the value of our first production and to serve as a comparison for the greater resistance secured in our later plates. Without giving details of the many experimental and ballistic trials to which our armor has been subjected, I have cited one of a seventeen inch nickel-steel plate, representing barbette armor of the Battleship "Indiana" similar to the "Illinois" and that which took place at Bethlehem's Proving Ground, July 30th., last, when the ten-and-one-half-inch nickel-steel Harveyized plate so completely pulverized the five eight-inch, 250 pounds Holtzer shells fired at a striking velocity of 1,700 foot-seconds, and aggregating an energy of 25,040 foot-tons. Both plates were subjected to unusually severe tests; in fact, very much more severe than the foreign standards. Against the first a 12-inch gun was used, the projectile weighing 850 pounds. Its dimensions were 8 feet 4 inches in height, 12 feet 1 inch in length, and 17 inches thick, forming a mass weighing 31½ tons. The striking velocity of the first shot was 1322 feet a second, and it penetrated to a depth of 16.6 inches, lacking less than half an inch of going through. The second shot was fired with a velocity of 1495 feet a second, and went three inches into the oak backing. The third and last shot was to determine whether or not the premium was to be paid, and the velocity was raised to 1858 feet a second. This perforated the plate but there were no cracks. These are the Firth-Firminy-Carpenter projectiles employed for the first and second shots. The results with the second plate although comparable from the same view, were even more remarkable.

In the one case we have a type of resistance which will keep out a

projectile of any calibre if thick enough, while in the other, a plate that will destroy the projectile until a calibre is reached whose smashing and racking energy will demolish the protection, although, perhaps at the risk of its own destruction.

In either case the heavy calibres will be needed.

This is a view of the result of the test of a 12″ ballistic plate representing the nickel steel barbettes of the "Maine."

The three 8″ Holtzer steel shells rebounded, their respective penetrations being 10½″, 10¾″ and 11″.

In testing the nickel steel ballistic plate representing the 12″ barbettes of the battleship "Texas," the plate was presented for a premium and three 8″ Holtzer steel shells were hurled against it with striking velocities of 1678, 2004 and 1835 feet-seconds.

Two of the shells rebounded but the second with its extraordinary velocity of 2004 ft. sec. succeeded in getting through.

The plate was a splendid one and no cracks developed.

These plates like the others made at Bethlehem were forged under the 125-ton hammer, a model of which stands in the Transportation Building. As steps in their manufacture may interest you I will present a few views showing a partially forged plate being withdrawn from the heating furnace; further reduction under the hammer; shaping it under the bending press; machining it to finished dimensions: an accepted lot ready for shipment to San Francisco for the "Monterey."

The first heavy nickel steel armor plate subjected to public test was the 10½″ tried in competition in the famous Annapolis tests. It came from the Creusot Works of Mr. Henry Schneider and was made under the direct supervision of Mr. Bouvard.

Before closing the first part of my paper I desire to call your attention to this view of the comparative sizes of the guns now used by our Navy with their projectiles and powder charges, commencing with the one-pounder and finishing with the sixteen-inch, 111½-ton gun.

All but the last have been made, and Bethlehem has had the honor of supplying steel for all the calibres up to and including the thirteen-inch.

This table contains the details of all Navy guns commencing with the four-inch, and I will leave it before you a moment for those who are not already familiar with its contents.

Turning to that branch of gun-making, wire-wrapped ordnance, I find it even more difficult to formulate any concise statement that can help you to form an estimate of its value. A large amount of experimentation has been carried on, but few practical results have been obtained.

In England remarkable velocities and ranges have been secured, but these have been equalled by the "hooped" gun; in Russia the guns test-

ed have shown great endurance, but in other countries nothing of importance has been done. In the United States, of the two guns tried one failed, while of the other (cast iron) the Board of Ordnance and Fortification has reported: "The muzzle energy of the gun is so much less than that of the steel gun, and the erosive so much greater that the Board for Testing Rifled Cannon does not recommend it as suitable for service under present conditions." It must be remembered that the tube of this gun is of cast iron, and that its rejection must not be ascribed alone to its belonging to the class of "wire" guns.

This type of construction, in one form or another, appears to antedate all others. In seeking for the earliest date when ring, hoop, or coiled guns were used, in order to mark the stages of transition, I have not been able to find anything earlier than the statement of Archdeacon Barbour that Edward III, with whom he was contemporary, employed cannon in 1327 in his campaign against the Scots.

Froissart refers to the general employment of cannon in 1340, but does not give until 1390 his first representation of the guns of the period. The next illustration of an iron gun is that of the battery of the "Mary Rose," a war vessel sunk in 1545. The gun, of which this is an approximate sketch, is said to have been recovered after an immersion of three hundred years. Both guns are evidently breech-loaders, and each is formed of a tube probably with a longitudinal lap (perhaps welded,) additional transverse strength being obtained by shrinking on the narrow rings shown in the sketches. These rings were supposed to be made from iron three inches square, and the earlier descriptions call them "immense rings." These "immense rings" have dwindled to 0.03″ section for wire, and developed (as the means of producing them have been provided) into jackets, for the 13-inch navy gun, for example of 38¼ inches outside, and 23¾ inches inside diameter by 204½ inches in length, weighing eighteen tons. The hoops or rings referred to above were driven over the tube or barrel when hot, the usefulness of shrinkage, although not carried to thousandths of an inch, being then recognized.

Both wire wrapping and wrought-iron coils are doubtless further developments of the barrel-welding of small arms. Greener says: "In the routine of good gunmaking, barrel-welding in importance is inferior only to the *quality of iron*," and that "the best barrels have more joinings than common ones of equal length." This would seem to be true of the modern wire-wrapped gun, since the greatest elastic strength is obtained with the smallest section.

Although with the ultimate object of producing tubes and hoops, the next prominent method of wrapping metal was that employed in the construction of the guns to which the names of Armstrong and

Fraser were given. The coiled-iron cylinders of Armstrong, which have received so much adverse criticism, may be taken as a species of wire-gun construction, a type in which the cross-section was excessive. The spiral winding and lateral welding gave slight longitudinal strength; but the material—iron—was not strong enough, and the guns were always unreliable. In referring to the system in 1882, Armstrong argued in favor of these coiled cylinders because the barrels of fowling pieces had long been made on the principle of welding a spiral coil of soft iron in a continuous tube, and he believed that coil cylinders of the continuous fiber of rolled iron would resist the more potent bursting strain, while the lateral welds would provide sufficient longitudinal strength. In practice, however, this proved not to be the case. This method of construction, although retained in Great Britain from 1857 to 1885 (probably the longest period held by any British type,) was not adequate, and many guns built in accordance with it came to grief.

To get longitudinal strength in his gun of 1860, Armstrong used an intermediate layer between the outer and inner coils, composed of iron slabs bent into cylindrical form and welded at the edges. The reason for this construction was that the intermediate layer has chiefly to sustain the thrust on the breech, and it is therefore desirable that the fiber of the iron should be in the direction of the length, while elsewhere in the gun it is more advantageously applied in the transverse direction. Armstrong here provided separate means for resisting the longitudinal and transverse strains, but did not separate them as Longridge does in his type. It is a point that might well be considered whether the increased friction resistance of the "shrinkage" form is not of more value than any tendency of separation that this friction might produce. In 1863 the coiled wrought-iron tube was replaced by a steel forging, but the wrought coiled strengthening hoops were retained.

The bars for these coils were all about 3″ × 5″ section 30′ lengths being end welded and wound upon a mandrel.

The coiled cylinders thus made were placed upon end, welded and shaped under a hammer until cylindrical hoops of the requisite length were formed. These lengths depended somewhat upon the capacity of coiling and welding machinery, but usually had to be made in short lengths because of the unequal welding of a large number of joints.

In 1867 Mr. Frazer, attached to the Woolwich establishment, simplified the Armstrong construction by reducing the number of coils, making them of thicker bars, and welding the trunnion band upon the breech coil; and in 1874 it was probably brought to its highest stage of efficiency when the 12-inch, 38-ton, muzzle-loading rifle composed of steel tube and wrought-iron coils gave a muzzle velocity of 1,410 feet seconds and a muzzle energy of 9,650 feet tons to a 700-pound projectile of 3 calibers length. In this gun the tube coils were welded from 4″

× 7″ section wrought iron, and the strengthening coils from 7″ × 12½″ section.

In Great Britian the change from wrought-iron coil ordnance to forged steel, when it did come, was rapid. An English authority writes: "In 1882, when a powerful British fleet engaged the forts of Alexandria, there was no heavy gun on board in the construction of which wrought iron had not been largely used; nor were there any heavy breech-loading guns; while to-day (1891,) on the contrary, all our modern iron clads are armed with breech-loading guns built entirely of steel."

The departure in both directions from Armstrong's wrought-iron coil construction resulted in an increase of strength. By way of the "Frazer" modifications the solid steel hoops and jackets were reached, while by way of thinner and smaller coils the wire system was perfected, in both cases steel becoming the accepted metal.

Although Armstrong's name has been welded to the coil construction, Blakely, I believe, had secured a patent for it before Woolwich and Elswick adopted it. The British patent records credit him with the idea.

The failures of the coiled iron guns showed them to be very deficient in longitudinal strength, the splitting of the inner coil and the separation of the coils being of frequent occurrence. Even with the low pressures employed, the wrought-iron coils were stretched beyond their elastic limit, and the barrel, not being adequately supported, gave way.

In the United States wrought-iron coils were extensively used for the conversion of Rodman and Dahlgren guns into muzzle-loading rifles. In the fabrication of the coil wrought-iron gun tubes, at the West Point Foundry, for the conversion of 10-inch Rodman smooth bore guns into 8-inch rifles, Lake Champlain pig was puddled and rolled into 23′ bars of 3.25″ to 4.0″ × 3.35″ irregular cross-section; these were scarfed to requisite coiling lengths by butt and lap welding, after which they were heated in long furnaces and coiled upon a taper mandrel operated by steam. The coils were then welded in banded cast-iron tubes called "welding pots;" after which the sections (Figure 7) were end welded to form the tube. In the Armstrong wrought-iron coils the cross-sections of the bars employed were 2.2″ to 2.5″ × 3.2″ for the 8-inch (Figure 8) and 3.05″ to 4″ × 5″ for the 12-inch tubes both of irregular cross-section. The coiling was done by Armstrong and at West Point by similar methods.

For forty years the names of Longridge, Woodbridge, and Shultz, and later Armstrong, have been prominently identified with "wire" gun experiments and development. To many others who have entered the race, reference will be made hereafter. Dr. Woodbridge's claim of

priority of the idea seems to be established by the record of a plan for a wire-wound gun presented to the War Department July 30, 1850. Although Blakely's name has not been frequently mentioned, a patent for the use of coils of wire for the strengthening of old and new guns was granted him February 27, 1853.

The early objects of wire construction were not only to increase the strength of guns, but to lessen the weight of the parts used in the construction of "heavy ordnance" before the advent of the mechanical means and metallurgical experience that have brought about the successful production of gun steel to so well meet the requisites of high power construction. Steel wire of small section and different forms was employed. The great increase of the elastic strength of steel by wire drawing enabled the requisite tangential cohesion to be easily secured, but the condition was complicated by an absence of adequate longitudinal or end strength. From a good wire steel of 75,000 pounds tensile and 37,000 elastic, physical qualities of 250,000 tensile and 200,000 elastic limit have been obtained in a square section of .07″, and in No. 22 music gauge steel wire the strength has run as high as 142 tons per square inch. While this high elastic strength is of great value in caring for transverse strains, it has not yet been successfully applied to decrease to any great degree the lack of longitudinal or end strength, which is an inherent defect of most wire-wrapped types. Longitudinal winding has been tried, but it increases the difficulty of manufacture; and the excrescences upon the tube or body of the gun often prevent uniformity in the metal, while the sudden changes of form interrupt the synchronous and elastic movement of the metal and produce rupture.

From the prolific literature on the subject I have selected the opinions of some of the men who have given the question careful thought and who have directed many of the experiments, and I have at least kept the system among its friends.

In respect to the use of steel wire of comparatively small cross-section or of steel ribbon, Armstrong claims, although his patent is dated December 28, 1880, to have given it his practical attention as early as 1855, and referred to it at considerable length in a lecture delivered before the British Institute of Civil Engineers January 10, 1882. He spoke of the system as being still in an experimental state, but believed it would attain wide application although there seemed many difficulties of putting the theories so strongly advocated into practice.

Armstrong also stated that in 1856 Mr. Brunel independently conceived the same idea as that presented by Blakely and Longridge, and requested him (Armstrong) to make a gun on the wire-wound principle; but that soon becoming acquainted with the priority of other pat-

ents the idea was given up by both Mr. Brunel and himself. In 1878 Armstrong's attention was again directed to the subject, when the patents already referred to having expired he made some preliminary experiments with small cylinders and in 1879 commenced the construction of a 6-inch breech-loading gun, which was completed and tested the following year. With it larger charges were used and higher energies obtained than with similar calibers of other types. As these results were satisfactory, a 26 cm. (10.23 inch) was constructed. It was 29 calibers long and weighed 21 tons. His 6-inch gun depended for longitudinal strength upon the cohesion of the barrel only, but in the latter (10.23 inch) he employed longitudinal layers of wire in the proportion of one longitudinal to four transverse layers. Of this particular construction Armstrong has written: "The longitudinals are secured to the trunnion ring at one end and to a breech ring at the other, and are in themselves calculated as sufficient to resist the end strains on the breech independently of the strength afforded by the tube. The whole is encased in hoops shrunk upon the exterior of the coil, for the treble purpose of protection from injury, of preventing slipping in the event of the failure of an external strand, and of adding to the strength of the gun. With regard to the ribbon form of section, I prefer it to a square section of equal area as being more favorable for bending over a cylinder; but any rectangular form is better than round wire on account of the flat bedding surfaces it affords." This gun when tested gave results unexampled, in relation to its weight, except by its 6-inch predecessor.

In 1884 Colonel Maitland referred again publicly to constructions "which involve the employment of wire, which may, perhaps supersede those consisting entirely of forged steel. They are chiefly experimental, but some have been made and actually issued for service to Chili by the firm of Sir W. G. Armstrong, Mitchell & Company. Competitive designs have been prepared for the War Office by the same great firm and by the Royal Gun Factory for guns of this kind. Figure 11 shows a section of the 18-ton wire gun proposed by Elswick. The Royal Gun Fectory design submitted at the same time is shown in the middle Figure. In this latter construction the whole of the metal over the chamber assists in supporting the transverse strain. The longitudinal strength is divided about equally between the tube and the outer hoops, and is ample."

This desire to diminish the weight of ordnance is not limited to any recent period. Several times in the history of gunmaking lightness of construction has been carried to excess with consequent reactions. Colonel Chesney and Captain Fave describe a method of construction to secure lightness in which different materials were employed from those now used for wire-wrapped ordnance; and if there had been a

patent union in existence in which Gustavus Adolphus could have secured a patent for the principle he might have reaped quite a valuable sum for royalties. These guns were made partly of boiled leather, and were used by Gustavus Adolphus at the battle of Leipsic, in 1631. They consisted of a thin cylinder of beaten copper screwed into a brass breech, the chamber of which was strengthened by four iron bands. The tube was covered with layers of mastic over the entire length of which cords were firmly wound, and equalized by a layer of plaster. A coating of leather, boiled and varnished, completed the piece.

In this description we find nearly all the elements of a principle of wire gun construction except the separation of the provisions for longitudinal and transverse strength. The gun was chambered, the chamber was jacketed, coils of rope provided tangential strength, while the leather covering protected the coils from injury.

In various papers read before the British scientific institutions the advantages of "wire" construction have been presented and frequently discussed by Armstrong, Maitland, Longridge, Bramwell, Jones and Hope. Many other authorities have spoken favorably of wire-wrapped ordnance, but since the appointment of Dr. William Anderson as Director General of Ordnance Factories the manufacture of wire-wound guns has rapidly progressed at Woolwich. Dr. Anderson has been interested in wire-gun construction for many years, and has always advocated the Longridge system.

The condition of the question in England in 1891 was well described in the issue of the London *Engineer* of October 2, 1891: "The points which in our judgment deserve attention specially in connection with the gun factories at present are the manufacture of wire guns and the behavior of steel under the action of the burning of the powder charge. Mr. Longridge may at all events at length have the gratification of seeing wire guns likely to come in on a sweeping scale. For several years past their superiority has been fully recognized."

In 1892 Dr. Anderson himself expressed the opinion that a large gun made of steel wire must necessarily be more reliable than a gun built up of forgings. He gave as his reason for this "that we know nothing of the internal molecular conditions of large masses of steel, whereas we know the exact state of structure built up of separate wires. Then, also, the tensile strength of steel wire is more than twice as great as that of a mass of steel." Dr. Anderson stated that they are conducting experiments with wire guns at Woolwich Arsenal, and that in all probability he will be able to give the results shortly.

Mr. Longridge has been the most persistent advocate of the application of wire to the construction of ordnance, and among the several forms that have emanated from the many inventors his last is undoubtedly the best type. His suggestions for the complete separation of the

longitudinal and transverse strength are valuable, and the use of the long jacket not only provides ample longitudinal strength, but serves to protect the wire from injury and displacement.

March 18, 1887, the British Parliament asked some questions "about a Longridge wire gun, said to have been made at Aboukoff, which had fired 1,500 rounds, and which was reported to have been made in half the time and at two-thirds the price of those now in the British service." The result was that the British Admiralty recommended that trials with wire guns should be pushed on, Mr. Longridge having confirmed the Russian statement that such guns could be made in half the time and at half the price of the British guns.

April 26, 1888, a 6-inch Longridge wire gun, which was being tested at the proof butts on Woolwich marshes, burst, blowing away a portion of the muzzle. The construction of this gun with the ruptures at *A* and *B* is shown in the Figure.

In May, 1888, Mr. Longridge wrote me of this accident to his 6-inch breech-loading gun.: "Its projectile of 99 pounds was fired with a 34-pound charge of pebble powder. The projectile moved quite freely in the grooves after it was once entered, and nothing in the way of wedging or jamming took place. The velocity was about 1,850 feet seconds, and the pressure gauge showed a pressure of about 25 tons per square inch. The muzzle ring and about eight inches in length of the cast-iron jacket were blown away to the butt, carrying away a gun-metal hoop that had been shrunk on to the end of the coil, uncoiling a small portion of the wire without breaking it. There was another fracture of the jacket about a foot to the rear of the muzzle ring, but this portion was only moved forward about one half inch in the coil. As the tube and coil were perfectly free to move forward in the jacket, except in so far as they abutted against the flange of the steel muzzle ring, it is clear that the whole of the strain which ruptured the gun must have arisen from the tube and coil moving forward, which in fact they did to the extent of about one inch. The causes of this movement were:

"The powder pressure acting upon the difference of area of the obturator and the section of the bore through the grooves.

"The friction of the projectile due to the reaction required to give rotation. The force required to bring back the tube and coil with the jacket in recoil.

"The friction of the products of combustion against the surface of the bore.

"The amount of this last, in the absence of direct experiments, is very difficult to estimate. I feel convinced that the accident to the gun at Woolwich was due to my underestimate of the effect of the friction of the products of combustion, and to a consequent error in the design of the gun."

Towards the end of 1891 Mr. Longridge sent me a copy of his letter to the London *Engineer*, in which he said: "It is in Russia only that my system has had a fair trial, and this is due to the energy and perseverance of Admiral Kolokoltzoff, chief of the Aboukoff works. You express a wish for definite data up to the present time respecting the first wire gun made in Russia. The gun was a 6-inch gun, breech-loading, with interrupted screw and DeBange obturator; length over all, 17 feet, 6 inches; weight 5½ tons; made at Aboukoff in 1888. After firing 1,000 rounds, with charges of 39½ pounds and projectiles of 122 pounds, the gun was taken to pieces and a new *A* tube taken, to which the same wire coil, jacket, breech apparatus, etc., were applied. The erosion of the chamber after the 600th. round of this gun is here shown, and was not enough to seriously affect its ballistics.

The gun was then fired 500 rounds, and the authorities being perfectly satisfied, the firing was not carried further. The operation of taking to pieces and rebuilding the gun was very quickly and easily performed, and the cost was practically that of the new *A* tube only, about one-fourth part of the weight of the gun. Since then they have made eight more 6-inch wire guns at Aboukoff, all of which have been perfectly successful, and thirty-two more have since been ordered by the Russian government. Guns of larger caliber are also under consideration, and in a recent letter from Admiral Kolokoltzoff, he speaks very confidently of their adoption ere long. I may perhaps also mention that experience has already proved the great economy of cost of the wire system over the forged steel guns and their much greater rapidity of construction. At last wire guns are recognized even at Woolwich. They are now making sixty of such guns. They are using my formula and are adopting my principle of separating the longitudinal from the bursting strain (Figures 15 and 16;) they are, in fact, practically making use of the principles which I have been advocating for nearly thirty-five years and which have proved to be correct."

Mr. Longridge claims that the government will save from 30 per cent. to 33 per cent. in first cost, besides having much stronger and safer guns. The section of wire to be used is rectangular, ¼ inch by $^1/_{16}$ inch. Its ultimate tenacity is 100 tons and its limit of elasticity 65 tons per square inch. The Longridge patents are, I believe, now owned by Messrs. Easton and Anderson, of London.

Germany has recently built a few wire guns that are reported to have given favorable results.

In France considerable attention has been given to the subject, and a number of guns have been manufactured; but the failure of the 34 cm. (13.4″) gun made at Fives-Lille in 1882 and the successful production of "hooped" guns have combined to stop any active development in the direction of "wire" methods.

Although large sums of money have been appropriated for this purpose, the Departments of the United States have not prosecuted this branch of gun construction with much activity. In 1882 General Benet called the attention of Congress to the serious consideration which artillerists in France and England were giving to the system of construction covering the use of steel wire or ribbon, and several boards subsequently recommended the manufacture and test of several guns of this system. Dr. Woodbridge having been given the credit of priority of invention, and being an American, his plans were adopted and followed until very recently, when two new types, the Crozier, called the Department gun, and the Brown Segmental Tube Wire gun, were recommended for test. The consequence is that one Woodbridge gun was tried and failed, another has been condemned as being of too low power, and three others await trial and completion. One of these is a 5-inch Navy breech-loading rifle, that has been fired a few rounds. These together with the Crozier and Brown constitute our experimentation in wire-wrapped ordnance. Other systems and types have been suggested, but difficulties of various kinds have prevented their completion.

The Board of Ordnance and Fortification, in its report for 1892, states for the Crozier wire-wound 10-inch breech-loading rifle, also known as the Ordnance wire-wound gun, being made from designs of the Ordnance Department, is approaching completion at the Army Gun Factory at Watervliet. This gun, as stated in the former report, consists of a steel tube, overlaid from breech to muzzle with a practically continuous covering of steel wire wound in layers, with a jacket cylinder enveloping the steel wire over the reinforce and a continuous layer of steel hoops covering the wire from the trunnion band forward to the muzzle. The coils of wire are electrically welded end to end, so that the gun is wound with a continuous strand of wire. The breech mechanism is of the usual service type. This high-power gun will be completed, and will doubtless be tested, during the coming year.

Captain Crozier advocates the use of castings for the jackets, but in this particular gun I believe the jacket is a forging. The general idea of the type is to have the wire as little interrupted as possible by hoops, etc., between the breech and the muzzle; to have the jacket take the longitudinal strain; and to so arrange the general construction that no part except the tube need be of expensive material, without any sacrifice of strength thereby.

As already stated, Dr. Woodbridge presented plans for the employment of wire in the construction of a gun as early as 1850, but the patent granted him in 1882 describes his present type in which "a cylinder composed of longitudinal bars or staves" is provided as "the chief resistance to longitudinal strains." Describing the wire he says:

"It should be either square or flat with a rectangular cross-section; should be 'tinned' or coated with a metal of low fusibility capable of being used as a solder. This serves as a preparation for soldering, or as a protection against oxidizing and to increase the resistance to slipping of wire upon wire." The wire drawn by the John A. Roebling's Sons's Company for the Woodbridge guns was $^1/_{10}$ inch square section (about No. 12 of their wire gauge) and gave an average tensile strength of about 170,000 pounds. The wire was tinned for brazing.

The Board on Heavy Ordnance and Projectiles reported in 1882 that: "A gun of 10-inch caliber, after the design of Dr. W. E. Woodbridge, was recommended for construction by the Board on Heavy Rifled Ordnance. This device involved a steel tube to be bound around by steel wire under the requisite tension, and to be united by brazing with bronze. The gun was constructed at Frankford Arsenal and submitted to a trial of 93 rounds, 83 of which were fired under the direction of this board. It burst into two parts (under longitudinal strain) just behind the trunnions, under a powder pressure of about 80,000 pounds to the square inch as measured by the Rodman gauge." The projectile weighed 390 pounds; powder charge, 75 pounds.

A 10-inch breech-loading rifle, cast-iron wrapped, was completed at the Watervliet Arsenal in 1891. This gun has a length of bore of 28 calibers, and weighs about 28 tons.

The Board of Ordnance and Fortification reported in 1892 that the gun has been fired 161 rounds and the test regarded as completed. It has thus far stood the tests to which it has been subjected, yielding velocities of 1,840 feet per second with a charge of 160 pounds of powder and a projectile of 453 pounds; they consider that the muzzle energy of the gun is so much less than that of the steel gun and the erosion so much greater that the Board for Testing Rifled Cannon does not recommend it as suitable for service under present conditions.

The 10-inch wire-wrapped breech-loading steel rifle built under the supervision of Dr. Woodbridge is practically completed. It consists of a continuous steel tube, overlaid throughout its rear half with a cylinder of closely fitted steel staves, the whole wound with tinned steel wire to be soldered or brazed in an oven. The whole length of the gun is divided into three sections by steel rings or bands, and forward of the staves the wire is wound directly upon the steel tube. It weighs 30 tons; is 27 feet long; the projectile weighs 600 pounds. The staves were annealed at the Washington Navy Yard. They were 24 feet long, four inches square, and weighed 1,290 pounds each.

The tension of the wire of the Woodbridge gun is adjusted and automatically regulated by a wire-tension apparatus patented by Dr. Woodbridge in 1885. The tensions of winding for the different layers are intended to give, when the interior pressure shall reach a little more

than 80,000 pounds per square inch, an extension to the wire overlying the chamber, in all its parts, equal to that due to a tension of 100,000 pounds per square inch in a "free" wire.

There are two features to the construction which Dr. Woodbridge considers important: to so machine and shape the longitudinal staves as to obtain a condition that will allow the employment of the whole contractile effort of the wire in opposition to the interior pressure, instead of having the resistance of the staves taking a share in it; and to winding wire with a curvature in order to reduce its tendency to unwind if cut. The accomplishment of the former would be accompanied by many mechanical difficulties, while the latter would scarcely seem to meet all the conditions of protection needed against the attack of heavy rapid-fire guns.

The correspondence of G. R. Lindsay and Lieutenant Whistler in issues of the New York *Times* of March 31 and April 5, 1891, relating to a prototype of the Brown wire-wound gun having existed thirty years ago, led me to look into the early histories of gunmaking for a segmental tube gun.

To show that the principle of using longitudinal segments or bars strengthened transversely is not new, I have presented some sketches of firearms of the period of 1330, taken from an *Elementary Treatise in the Forms of Cannon and Various Systems* translated in 1832 from the French of Prof. N. Percy, of Metz. In describing them he says: The first firearms, which were called bombards and cannon, were fabricated of iron. These arms were very short and of a great caliber, and were made of bars of iron arranged in a cylindrical form and bound together by bands of the same material. They projected pieces of iron and stones, and were fired under great angles. Subsequently they were forged in a single piece, and among the most remarkable of this period, some had outside and inside the form of a frustum of a cone, the small diameter corresponding to the breech which terminated in a conical screw; others had the form of a cylinder, or were reinforced throughout a great portion of their length towards the muzzle. Some of these had a chamber for powder, and their reinforce extended throughout the length of the bore; the bore was eight times the diameter in length, which was 13″; the width of the chamber was one third of the diameter of the bore, and the depth of it four thirds. All these arms were strengthened by a swell at the muzzle and breech, and by bands at different intermediate points. They had neither trunnions nor handles. According to Thieroux, the first cannon were conical and shaped like an apothecary's mortar or vase, they were called mortars, vases, or bombards. The first change was to a chambered gun with a cylindrical bore, but the chamber was of a less diameter than the bore. Because these cannon fired stone projectiles they were called *perrieres*. They were made

of iron bars bound together with bands like a barrel.

Mr. Brown claims that the fundamental principle of his gun lies in the segmental tube and not in the wire wrapping. He has never asserted that he was the inventor of the wire gun, nor that the use of the segmental tube was new; but he believes that the idea of subdividing a core for the purpose of obtaining special elasticity is original with himself, and that thereby it is possible to set up such a high degree of initial compression that even under the highest powder pressure the compression at the surface of the bore will not be reduced to zero. To present the views of the advocates of this principle of gun-making, I have taken the following description from the literature of Lieutenant Whistler, the company's engineer:

"The Brown Wire Gun consists essentially of a segmental core wound with wire under such tension that the compression between the longitudinal segments of the core induced thereby will be more than sufficient to resist all ordinary powder pressure. The longitudinal segments are primarily held together by a breech and muzzle nut screwed on hot, with the proper degree of shrinkage, so that the tension of the nut adjoining wire will be the same after winding. The wire is wound between the nuts under a high degree of tension, and anchored by a special device. The trunnions are not attached to the core or body of the gun but to an outer trunnion jacket, which jacket is attached to the gun proper by means of the breech nut. By this means the recoil is transmitted to the trunnions through the breech nut and jacket, and the core or body of the gun is thus relieved from the major part of the longitudinal thrust due to powder pressure upon the bottom of the bore. The gun itself is free to expand longitudinally within this jacket, which is attached only to the breech nut. The essential feature of the gun is, of course, the segmental core. This core consists of a number of longitudinal steel segments, the number being so regulated that the maximum thickness of a segment shall not exceed one half inch materially. The chase jacket consists of a series of interlocking hoops shrunk on over the wire extending from just in advance of the trunnions to the muzzle, the entire jacket being held in place by a muzzle nut, the thickness of which and the amount of shrinkage being so adjusted that when completed the compression produced by the built-up muzzle nut will be the same as that produced by the wire and chase rings."

During the progress of the work, which has been extended over a period of three years, mechanical difficulties and the results of the trials of experimental cylinders representing sections of the powder chamber gave reason for decreasing the number and increasing the size of the longitudinal segments and the necessity for the insertion of a lining tube to prevent the entrance of the powder gas between the seg-

ments, which, in the case of one of the experimental cylinders, was so great as to cause marked discoloration at the joints. The lining tube was inserted under initial tension and extended to about five or six calibers in advance of the front end of the chamber. This tube can be removed and replaced by a new one whenever it becomes too much eroded for service. Recalling the unfortunate experiences of the Maitland half-liners in England, this would appear to be but another invitation for the erosive action of the powder products.

The advantages claimed for the system are: "1. In consequence of the small weight of each of the component parts of the gun, crucible steel can be used economically. 2. The small size of the segments and the ingot from which they are rolled admit of being carefully cast and uniformly forged, so as to insure uniformity of metal, and of being thoroughly annealed. 3. They can be readily rolled into shape; that is, the method of construction is exceedingly economical. 4. They can be thoroughly and conveniently inspected. 5. The size and thinness of each segment insure a thorough and uniform tempering and annealing, if temper be considered desirable. 6. The size of the segments admits of readily setting up conditions of special elasticity by cold work. This latter feature is by far the most important one in this system of construction, as it renders it possible to use a character of steel far beyond anything heretofore employed in the core of a gun."

If the segments compressed by the full elastic strength of the wire present an interior surface that can withstand the erosive action of the powder products, we must admit that Mr. Brown has supplied a method of forming the bore of the gun which has decided advantages; but if recourse has to be had to a liner to resist erosion we return to a core that will not sustain the full elastic strength of the wire, and it probably will be more economical to use a steel tube of suitable dimensions than a combination of segments and thin liners, unless these liners, like the segments, are cold drawn, and thus by a great amount of mechanical work rendered impervious to the serious ravages of the powder products.

Even if the 5″ experimental gun now approaching completion successfully meets all the conditions that its projector and engineer claim for it, it will still remain to be proved if all the mechanical conditions can be met in guns of larger calibers. The experiment is an interesting one, and if the type is not absolutely new the method of construction is, and all the theory in connection with it is being ably and fluently presented.

It is evident from the various plans and suggestions I have called to your attention that very few attempts were made to apply the individual parts to a service of their individual and separate capacities, and that the attempts to unite in one mass the integral parts resulted

in impairing the integral strength and a consequent reduction in the strength of the whole. This separation, however, has been successfully accomplished in the Longridge gun and mortar and it is being done in the "hooped" system as well.

In the de Brynk construction the tangential strength may be provided by wire-wrapping without interfering in any way with the advantages claimed for it; namely, turning the core of the gun upon its main axis when the scoring of any part renders such operations necessary, separating the gun into masses to facilitate transportation and assemblage and to decrease the size of the machinery required for the manufacture of its parts.

All accidents to wire-wrapped guns point to the absence of adequate longitudinal strength. After a careful consideration of the many devices that have been suggested to meet this defect, that of supplying this quality by long forged steel hoops seems the simplest and most effective.

When considering the argument so often presented that there will be a saving of weight, remember that the reduction of weight in the gun must be provided for in carriage and recoil, and that we have now replaced the expression "heavy ordnance" by that of "high power ordnance," because we have gained the power without additional weight of metal, and in many cases by a marked decrease of it. All welding can now be done by electricity; weak spots can thus be avoided and continuous winding easily effected.

When many of the objections to wire-bound guns were raised wrought iron and iron wire were generally employed, and the mechanical means of shaping and machining were more or less imperfect. Whitworth used some steel, and his mechanical devices led the world, but were infants in comparison with present appliances.

The advantages claimed for the wire system of construction are:

1. That steel in small sections can be obtained that possesses greater strength than is possible to get in any other form.

2. That each layer can be brought truly to its correct tension.

3. Flaws of manufacture can be easily detected, and if not discovered are confined to that part in which they exist.

4. The parts of the gun are light and can be more certainly and easily produced and assembled.

5. For their manufacture expensive and complicated plants are not needed.

In comparing the reported results of the tests of the various types we must not forget that these experiments have been carried on in various parts of the world, in places very far distant from each other, under different methods, inventors, and circumstances. In the majority of cases they have required to produce them much special machin-

ery which if employed in subsequent production would materially reduce the cost of the guns turned out. In some cases the inventors have been employed to superintend or advise concerning the construction or the preparation of tools or machinery necessary to carry out their special and in some cases peculiar ideas ; all these circumstances have combined to make the cost of the experimental guns very great. On the other hand, the inventors or advocates in estimating the comparative cost and time of production have given themselves every benefit. As these guns have never become commercial service products on any large scale (I believe Russia has manufactured a larger number than any other nation), it is impossible to make any reliable comparison of their cost and the time required for their production.

The wire-wrapped type had the honor of firing the "Jubilee Rounds" in the Queen's Jubilee Year, and gave wonderful results. On April 16, 1888, was fired at Shoeburyness the first of a series of rounds intended to investigate the conditions attending firing at very long ranges. The gun selected was a 9.2 gun, made under the direction of General Maitland in the Royal Gun Factories. The weight of the gun was 22 tons; that of the projectile 380 pounds, which, fired with a charge of 270 pounds, gave a muzzle velocity of 2,360 feet seconds. The elevation of the first round was 40°. The projectile fell at a range of about 21,000 yards, or nearly twelve miles. On July 12, at 43° elevation, a range of 21,600 yards was attained, and on July 26 with 45° elevation, the range was 21,600 yards, or about 12.4 miles. The projectile remained in the air about 69.6 seconds, and its trajectory reached a height of 17,000 feet, or about 2,000 feet higher than the summit of Mont Blanc.

Comparing the velocity, however, with a more recent 6-inch quick-firing gun (hooped) a velocity of no less than 2,669 feet has been realized with a 19½ pound charge of cordite.

It is easier for the historian to criticise than for the engineer to prophesy ; consequently we should not only be grateful for the failures upon which many of our successes have been based, but also remember that the constructions which subsequently proved so inadequate were marked improvements over those which went before. Further, they should be looked upon and their value estimated from a standpoint and comparison of the periods in which they were suggested. Lecky in his *The Art of Writing History* said : "A fatal and very common error is that of judging the actions of the past by the moral standard of our own age." Scientific accomplishments at present are like clearing-house settlements—completed today only to be changed tomorrow.

The lecture was profusely illustrated with lantern views, about one hundred and eighty different ones being shown.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

BOSTON SOCIETY OF CIVIL ENGINEERS.

OCTOBER 18TH, 1893:—A regular meeting of the Society was held at its rooms, 36 Bromfield Street, Boston, at 7:45 o'clock p. m. President Freeman in the chair. Fifty-nine members and nineteen visitors present.

The record of the last meeting was read and approved.

Messrs. John N. McClintock, George L. Mirick, Walter H. Norris and Chester W. Smith were elected members of the Society.

The President announced the deaths of two members of the Society, that of Charles W. S. Seymour of Hingham, which occurred Oct. 15th, and that of Frederick H. Barnes of Waltham, which occurred Oct. 16th. The President was authorized to appoint committees to prepare memoirs. Messrs. M. M. Tidd, C. W. Howland and F. M. Hersey were appointed the committee on memoir of Mr. Seymour, and Messrs. A. F. Noyes, G. A. Kimball and H. D. Woods on that of Mr. Barnes.

The discussion on the Construction of Reservoir Embankments, begun at the last meeting, was then resumed.

The Secretary read a communication on the subject from Mr. A. Fteley, member of the Society.

A very interesting communication was also read, prepared by Mr. E. F. Smith, engineer of the canal department of the Philadelphia & Reading R. R.

A letter was read from Mr. Charles C. Campbell of Lawrence, Mass., a mill-wright of large experience, giving his testimony as to the value of clay as a preservative for sheet-piling and wooden flumes.

Mr. J. Waldo Smith, assistant engineer of the East Jersey Water Co., contributed a paper on The Compacting of Earth in Dams and Embankments.

Mr. Desmond FitzGerald closed the discussion of the evening with an account of some of the dams built in India.

During the meeting a number of photographs were shown by Mr. G. A. Nelson showing the slip in the slope pavement of the Lowell Reservoir, which occurred some years ago.

Adjourned. S. E. TINKHAM, Secretary.

CIVIL ENGINEERS' CLUB OF CLEVELAND.

NOVEMBER 14TH., 1893.—Meeting was called to order at 7:45 o'clock by the President. Fifty-five members and visitors present.

The record of meeting held on Oct. 10th., was read and approved.

The tellers announced the unanimous election to active membership of the following: Wm. C. Jewett, A. Lincoln Hyde, Frank H. Constant, John G. Schmitt and Henry Grey.

Letters were read from the German Engineering Society and from the American Society of Engineers and Architects, acknowledging courtesies extended at Chicago in connection with the World's Fair and extending thanks for the same.

A report from the committee on quarters was presented by Mr. C. W. Wason to the effect that changes in Case Library Building were in contemplation and that the needs of the Club were being considered.

Mr. Benjamin read a letter directed to the Board of Managers announcing the election of Prof. J. B. Johnson to the office of President of the Association of Engineering Societies and the election of John C. Trautwine to position of Secretary of the same body.

The President appointed Mr. C. W. Foote, a member of the programme committee, to succeed Mr. Uebelacker, resigned.

On motion to that effect the President appointed the following committee to prepare a suitable memorial to our lately deceased member, John H. Sargent: E. E. Boalt, C. H. Strong and J. F. Brown.

Mr. W. H. Searles then presented a paper on the "Ferris Wheel," which was discussed by Prof. J. W. Langley, C. F. Lewis, W. R. Warner, Geo. E. Gifford, Ambrose Swasey, F. C. Osborn, A. H. Porter and N. P. Bowler.

Meeting adjourned at 9:50 o'clock to an informal social at the rooms of the Correspondence School of Technology in the Brainard Block.

F. C. Osborn, Secretary.

ENGINEERS' CLUB OF ST. LOUIS.

386th. Meeting, October 18, 1893.—The club met at 8 p. m. at the club rooms, President Moore in the chair and twenty-three members and one visitor present.

The minutes of the 385th meeting were read and approved.

The Executive Committee reported their action at their 148th meeting.

Messrs. A. M. Lockett, A. W. Dickens, A. Schnadelbach and C.G. Reel were elected to membership.

The Executive Committee reported in favor of giving up the present quarters.

It was moved and carried that the Executive Committee be instructed to give up the present rooms of the club and make arrangements, if possible, to meet at Washington University.

Prof. Johnson presented a copy of "The Theory and Practice of Modern Framed Structures," by J. B. Johnson, C. W. Bryan and F. E. Turneaure.

On motion a vote of thanks was given to Prof. Johnson.

The paper of the evening on "Landslides and their Prevention," as illustrated in some noted examples on the German government railways, by D. A. Moliter, was read by Prof. Johnson.

The paper discussed the various causes of landslides in cuts and on embankments, in different kinds of soils, and gave the details of many noted cases, and the methods used to stop them, all illustrated with full

plates. It also presented a new theory of equilibrium of earth slopes and pressures against retaining walls.

Discussion followed by Messrs. Dean, Crosby, Judson and Ferguson.

Adjourned. ARTHUR THACHER, Secretary.

387TH. MEETING, NOVEMBER 1ST, 1893.—The club met at 8 p.m. at the Washington University, President Moore in the chair and twenty-six members and two visitors present.

The minutes of the 386th. meeting were read and approved.

The Executive Committee reported their action at their 149th meeting.

Messrs. R. McCulloch and A. L. Tuttle were proposed for membership.

Communications from the German Engineering Society and Austrian Society of Engineers and Architects, thanking the American engineering societies and clubs for courtesies during the Columbian Exposition were read.

Prof. Johnson described Col. Flad's new suction dredge boat and presented full detailed blue prints illustrating its construction.

Discussion followed by Messrs. Wheeler, Moore, Bounton, Curtis, Hermann.

Adjourned. ARTHUR THACHER, Secretary.

WESTERN SOCIETY OF ENGINEERS.

308TH. MEETING, NOVEMBER 1ST, 1893.—The 308th meeting of the Society was held at No. 10 Van Buren street, Wednesday, November 1st, 1893, at 8 p. m. 15 members and guests present.

In the absence of the President 2nd Vice-President Hiero B. Herr took the chair.

The reading of the minutes of the last meeting was dispensed with.

The chairman called for the report of the Board of Directors, which included the following:

Elected to membership: Messrs. James F. Lewis, A. P. Vedel, H. V. de Hart.

The application of Mr. Francis H. Bainbridge was placed on file.

Bills to the amount of $60.25 were ordered paid.

The Board of Directors also called for the action of the Society on the donation, consisting of books, periodicals, maps and pictures, presented to the Society by the Associated Engineering Societies, on the closing of their headquarters at 10 Van Buren street.

The chair further explained the donation and Mr. F. H. Davies moved:

"That a vote of thanks be tendered to the committee of the Associated Engineering Societies for their donation to the Western Society of Engineers." Seconded and carried unanimously.

There being no further business before the Society, the chair called for the paper of the evening: "Irrigation—Some Practical Notes on the Engineering and Practical Features of the Question," by A. M. Van Auken, which was read by the author.

The paper was received with interest and occasioned a general discussion, among those participating being: Messrs. Appleton, Karner, Weston, the Chair, Ewing and Barlow.

Adjourned. JOHN W. WESTON, Secretary.

MONTANA SOCIETY OF CIVIL ENGINEERS.

DECEMBER 9TH., 1893.—The meeting was called to order by President Haven; five members present.

Applications for membership were presented from Prof. R. E. Chandler, M. E., of the Montana College of Agriculture and Mechanic Arts, Bozeman, Mont., and Prof. E. H. McDonald, E. M., of the School of Mines, College of Montana, Deer Lodge, Mont. The applications were ordered referred to the Trustees.

The Trustees having reported favorably on the application of S. T. M. L. B. Kneeland, the Secretary was instructed to send out letter ballots for the next meeting.

Mr. Herron was excused from reading his paper until the Annual Meeting to be held January 13th. No further business offering, the Society thereupon adjourned.

G. O. FOSS, Sec'y

ASSOCIATION OF ENGINEERING SOCIETIES.

ORGANIZED 1881.

Vol. XII. December, 1893. No. 12.

EXPERIMENTS ON THE COMPRESSIVE STRENGTH OF STEEL HOOPS.

BY CHAS. H. BENJAMIN, MEMBER CIVIL ENGINEERS' CLUB OF CLEVELAND.

[Read Sept. 12, 1893.]

The experiments I am about to describe were made under my direction in the testing laboratory of the Case School of Applied Science, by Mr. Geo. I. Allen, a member of the senior class.

The subject was suggested to me by Mr. W. H. Searles of this Club, to whom I am also indebted for other suggestions as to the conduct of the experiments.

The hoops used were made of soft steel boiler plate, having a tensile strength of about 60,000 lbs., and a modulus of elasticity of about 30,000,000, cut into strips about 2½″ wide, bent and welded.

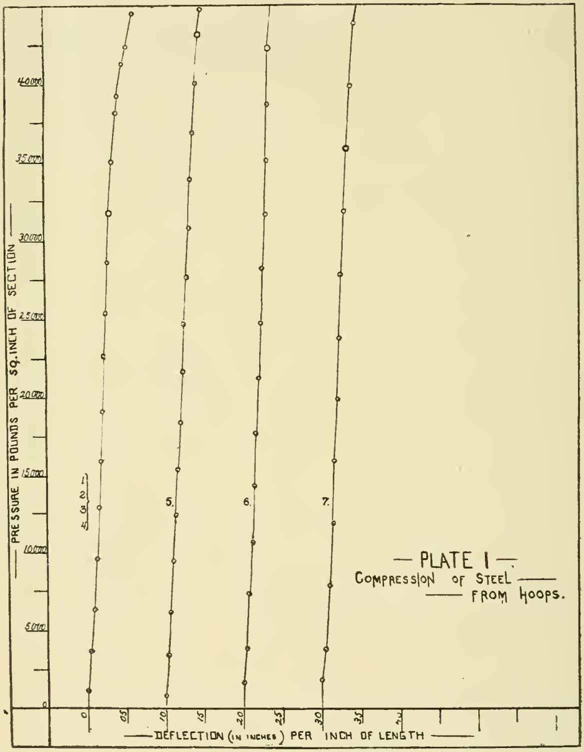
The material varied in thickness from ¼ inch to ½ inch, and the hoops were of diameters varying from 9 inches to 18 inches.

Samples of the steel used in each hoop were first tested by tension, and the elastic limit carefully determined by the use of an extensometer. (See Plate II.)

The hoops were then tested by direct compression in two groups, (1,) hoops of the same thickness of metal but of different diameters. (2,) hoops of the same diameter but of different thicknesses of metal.

In each test as successive increments of load were applied, careful measurements were made of the internal diameters both vertical and horizontal. In every case after a certain limit was reached, the hoop bent at the extremities of the horizontal diameter and resistance to compression rapidly decreased with increasing set, as is indicated by the curves in Plates III and IV.

Finally a piece was cut from the uninjured portion of each hoop, straightened and subjected to direct compression in the testing machine. Each piece was gripped at one end in the jaws of the machine, and the other end pressed vertically against a hardened steel block, the free length in each case being ten times the thickness of metal. The



elastic limit was determined as with the tension pieces. (See Plate I.)

It is apparent from inspection of the curves in Plates III and IV that the change in both vertical and horizontal diameters is nearly proportional to the load within the elastic limit.

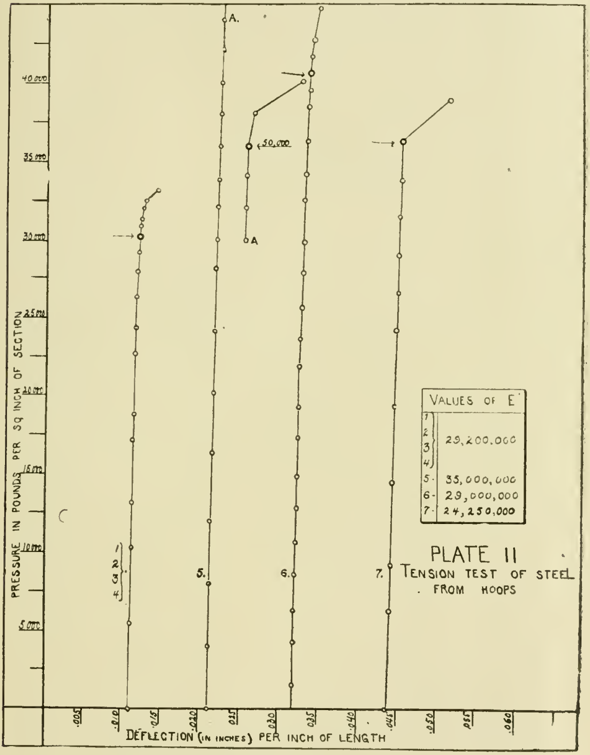
Let us regard the hoops as composed of two bent columns, united at the top and bottom and each having a constant deflection equal to

one-half the horizontal diameter. (The change in this diameter within the elastic limit is so slight as not to affect the results materially.)

Let P = load in pounds at elastic limit.

" D = inner horizontal diameter in inches.

" b = breadth of ring in inches.



" d = thickness of ring at A or B.

" S = total stress on inner fibers at A or B due to load P.

Then as in Gordon's formula for columns may we regard S as due to the sum of direct compressive stress and the stress due to bending, or:

$$S = \frac{P}{2\,b\,d} + \frac{6\,M}{b\,d^2}$$

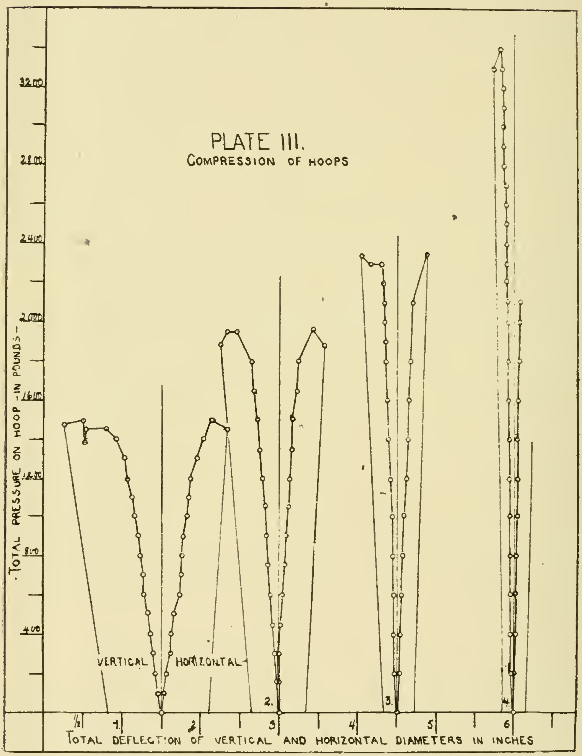


PLATE III.
COMPRESSION OF HOOPS
TOTAL PRESSURE ON HOOP - IN POUNDS -
3200
2800
2400
2000
1600
1200
800
400
VERTICAL
HORIZONTAL
2.
3.
4.
½
1
2
3
4
5
6
TOTAL DEFLECTION OF VERTICAL AND HORIZONTAL DIAMETERS IN INCHES

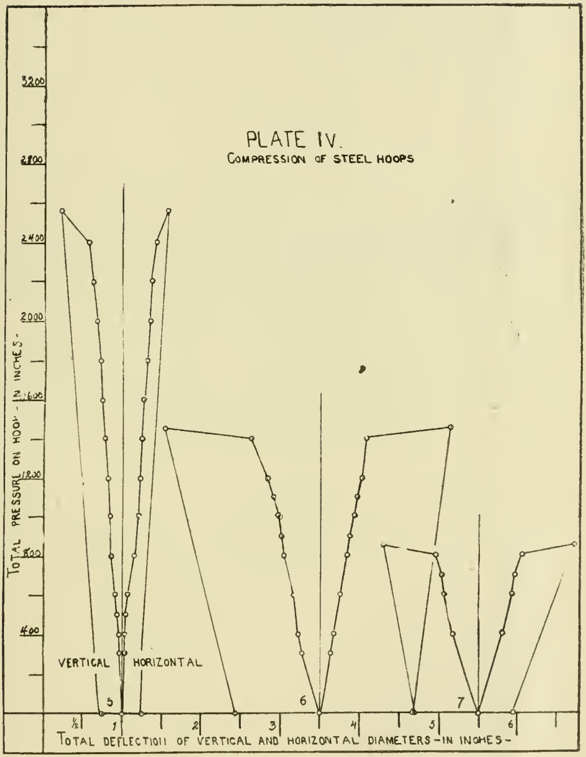


PLATE IV.
COMPRESSION OF STEEL HOOPS
TOTAL PRESSURE ON HOOP - IN INCHES -
3200
2800
2400
2000
1600
1200
800
400
VERTICAL
HORIZONTAL
5
6
7
½
1
2
3
4
5
6
TOTAL DEFLECTION OF VERTICAL AND HORIZONTAL DIAMETERS - IN INCHES -

where M is the unknown bending moment at A or B. But M may be assumed to be proportional to

$$\frac{P}{2} \times \frac{D}{2} \text{ or: } M = k \frac{P D}{4}$$

$$\text{and } S = \frac{P}{2\,b\,d} + \frac{3\,k\,P\,D}{2\,b\,d^2} = \frac{P}{2\,b\,d}\left(1 + \frac{3\,k\,D}{d}\right)$$

$$\text{Let } 3\,k = q,$$

$$\text{then } S = \frac{P}{2\,b\,d}\left(1 + q\,\frac{D}{d}\right) \qquad (1)$$

where q is a constant to be determined by experiment, whose value is:

$$q = \frac{2\,b\,d^2\,S}{P\,D} - \frac{d}{D} \qquad (2)$$

As S is undoubtedly a compressive stress, it seems reasonable to assume that it will be nearly equal to the elastic limit of the material as determined by direct compression.

In Table I, are arranged the values of the different quantities as determined by measurement and experiment. The material of the hoops 1 to 4 inclusive was cut from one plate. On account of the difference in thickness this was not possible with the other three.

It will be noticed however that the values of the elastic limit for tension and compression agree fairly well in all the experiments except No. 5.

TABLE. I.

No.	Vertical Inside Diameter D^1.	Horizontal Inside Diameter D.	Breadth b.	Thickness d.	Elastic Limit Tension.	Elastic Limit Compression S.	Elastic Limit of Hoop P.	Change in D^1 under P.	Change in D under P.	Average Change.
1	17.27	17.38	2.39	0.397	30850	31810	1400	0.57	0.52	0.545
2	14.23	14.29	2.375	0.397	30850	31810	1800	0.35	0.23	0.29
3	11.27	11.25	2.406	0.405	30850	31810	2300	0.22	0.20	0.21
4	8.08	8.19	2.39	0.397	30850	31810	3400	0.18	0.17	0.175
5	15.03	15.09	2.344	0.429	50070	43070	2200	0.37	0.37	0.37
6	15.10	14.98	2.344	0.307	40680	42240	1400	0.88	0.68	0.78
7	15.03	15.02	2.344	0.277	36370	35820	800	0.55	0.44	0.50

Substituting values from the table in formula (2,) we get the following values for q:

No.	1	2	3	4	5	6	7
q	.9623	.8983	.9345	.8122	1.0913	.8694	1.0541

and an average value:

$$q = .946$$

Substituting this value of q in (1) and solving for P, we have:

$$P = \frac{2\,b\,d\,S}{1 + .946\,\dfrac{D}{d}} \qquad (3)$$

as the load at the elastic limit.

AMOUNT OF DEFLECTION.

It is apparent from Plates III and IV, that the change in both vertical and horizontal diameters increases as the load, within the elastic limit, the elastic curves being approximately straight lines.

Let x = variation in horizontal diameter.
" y = " " vertical "

Then x and y vary as P.

In Table II are shown the values of x and y under the same load for different diameters of hoops, and in Table III the values of x and y under a constant load for different thicknesses of metal.

TABLE II.

No. of Hoop.	1	2	3	4
Average Inside Diameter D.	17.32	14.26	11.26	8.14
Average Thickness, d.	.398	.397	.405	.407
Breadth, b.	2.39	2.375	2.406	2.39
x.	.370	.130	.110	.040
y.	.420	.217	.095	.056
Average $\frac{x+y}{2} = z$.	.395	.173	.102	.048
z From formula, (4)	.450	.255	.117	.044

Load, 1200 lbs. in each case.

TABLE III.

No. of Hoop.	5	6	7
Average Inside Diameter, D.	15.06	15.04	15.03
Average Thickness, d.	.425	.307	.277
Breadth, b.	2.344	2.344	2.344
x.	.150	.330	.440
y.	.120	.460	.550
Average $\frac{x+y}{2} = z$.	.135	.395	.495
z from formula, (4)	.122	.329	.528

Load, 800 lbs. in each case.

From the values given in these two tables it can be shown that the average distortion, z varies nearly as $D^{2.8}$ and inversely as $d^{2.9}$. It may be assumed that z will be inversely proportional to b and S.

The small number of experiments made forbids anything more than a tentative formula and we will therefore assume:

$$z = \frac{P\left(\frac{D}{d}\right)^3}{a\,S\,b}$$

where a is a constant to be determined from the experiments.

The values of a thus determined are:

No.	1	2	3	4	5	6	7
a.	3289.	4254.	3301.	2630.	2611.	2405.	3075.

Neglecting No. 2, in which for some reason the distortion was abnormally small as seen in table, we have average of six trials:

$$a = 2885$$

$$\text{and } z = \frac{P}{2885} \cdot \frac{\left(\frac{D}{d}\right)^3}{S\,b} \qquad (4)$$

This short preliminary investigation shows in what direction subsequent experimenters may work, and that a large number of experiments are needed to gives values of the constants, which would be at all reliable.

The motive of this investigation was to obtain data for designing large steel tubes exposed to an external crushing load, and as far as I can learn is the first attempt to derive formulae for such a purpose.

DISCUSSION.

MR. F. C. OSBORN: How do you arrive at the value of S in that formula? You have two unknown values: S and Q.

PROF. BENJAMIN: The large S is the stress per square inch at the extremity of the horizontal diameter.

MR. OSBORN: Where the hoop changes its shape?

PROF. BENJAMIN: Yes. I take a straight specimen and crush it till I get a sharp point in the curve on the profile. Then I divide that load by the area of section and call that S.

MR. OSBORN: Why would it not do to measure the elongation very carefully, and then, from the modulus, compute the exact strain on that fiber?

PROF. BENJAMIN: Of course you have to get your modulus from the material.

MR. OSBORN: Yes; and then make the measurement as carefully as it can be made; and then you get the exact value for Q.

PROF. BENJAMIN: The reason I adopted my method was, because it was the shorter cut; the conditions seemed so nearly analogous in the two cases. The encouraging feature is, that these values come so nearly constant.

MR. OSBORN: Gordon's formula is quite a good proof of this, I think.

PROF. BENJAMIN: I think myself that anybody who uses Gordon's formula every day has no fault to find with this.

MR. OSBORN: I want to take a stand in favor of Gordon's formula. Experiments do not always agree with the formulae, but, I think, the fault is with the experiments. Gordon's formula is based on the elastic properties of the material. If you put a column into the testing machine, and continue the experiment until the column fails, you pass the point where you can prove or disprove Gordon's formula. I think the best way is to make the measurements of elongation and compression before the material has reached the elastic limit.

PROF. BENJAMIN: I agree with Mr. Osborn. I have nothing to say against Gordon's formula only that the man using it on a particular kind of column must determine the constants for that kind of column. If he is dealing with a round column, he must make experiments with round columns. I think a great mistake has been made in doing so much work beyond the elastic limit. I think what we want to know is the behavior of material inside the elastic limit, and be guided entirely by that.

Mr. W. H. Searles: If we had the genius of a LaPlace, and the leisure, we might figure out the action of a ring under such circumstances as here described, and find a formula that would meet all the conditions for a certain material. But if the material is homogeneous and without internal strain, and the ring is a perfect circle resting on a horizontal bed, we may safely assume that the ring will take the form of an ellipse under a single vertical load. In the ellipse obtained under such circumstances a molecular change takes place all the way around; it is not a sudden bending at the extreme points of the horizontal diameter; and just in that respect it seems unsatisfactory to base all our calculations upon what goes on at the extremities of that diameter. But the results brought out are very satisfactory, considering the small range of diameter and thickness used, the latter varying from .27 to .43; and it may be that some slight errors in the variables are compensated in part by the value found for the constant. The load per unit of length that a ring or tube will carry safely, before it begins to collapse seriously, is the problem that I wished to have solved. Nothing could be found on this subject in print by myself, and I examined pretty thoroughly in this city and Chicago in various libraries. Hence I appealed to our fellow member to see what could be learned from experiment. Now as in the case of a long column, it may be true also in this case that a formula, though it be empirical, is better than one entirely theoretical. There may have been initial strain in the material when it went into the testing machine. Since it was bent into a circle by force, we see that the flattening under a load would tend to relieve the strain at the top and bottom, whereas the bending at the sides would increase the initial strain. Hence the elastic limit would be sooner reached at these points. The formulae agree, however, with those particular rings very well indeed, and are worthy of consideration and acceptance, at least in this stage of the experiment. It may be that a larger number of experiments produced at some future time will seem to modify the view now taken.

Given, a circular tube or ring and the limit to the load it will carry, the next question is how great will the compression be under a given load, the load being within the elastic limit of the ring? S is to be found by direct experiment upon the material.

Prof. Benjamin: I would determine S for that material once for all.

Mr. Searles: The constant S is to be obtained by direct experiment, leaving the constant A to be determined; but this A is also dependent upon the quality of the material. I found in my formula the same numerator as Prof. Benjamin has given, but for my denominator I prefer to introduce the co-efficient of elasticity E, of the material, so that the formula reads

$$z = \frac{P\,D^3}{4.13\,E\,b\,d^3}$$

The co-efficient of elasticity was taken from values given me when the material was tested for tension in a straight piece. If we had a great many more experiments we might refine these constants: but for a rough purpose in the present state of the art this is the formula that I think safe to adopt.

PROF. J. W. LANGLEY: I think there is one point that should be considered when we pass to the consideration of the actual stress necessary for the crushing of the tube. These rings, I presume, are made out of a sheet which was rolled latitudinally in the direction of the of the ring. The actual tube is made from the sheet rolled up: I think that would make some difference in the strength of the material. It has been asserted that there is no fiber in steel. I am very sure there is a fiber in hard steel; that can be very easily shown. The fact is well known in rolling mills that steel has a fiber. Take a 4 or 5 inch ingot and break it down under a hammer and cut it across, and then etch it with acid and examine it under a microscope, you will find it has a fiber. Let that cool down to dark red, make an octagon of it, and unless the material is extremely sound you will find, if you etch it again, all the fiber in concentric circles. A piece that may be drawn down to an indefinite size if kept square, will burst and go to pieces if you try to make an octagon, and also if you try to makeit round. There are three ways of making a tube. A tube made like these rings would be bending it at right angles to the fibre. There is a component lying across the fibre. The greater part of the fiber is running along parallel to the circumference. Of course this fact of the different modes of making the tubes does not change the excellence of Prof. Benjamin's formula, but it will change the value of these constants. Take a tube and saw off the ring, and then we have a section of the tube in the actual condition of the fiber line, and the results would be extremely close to the results on the tube itself.

MR. L. HERMAN: Experiments were made on tubes which were comparatively small in diameter in relation to the thickness—fifty to one. How would the result be if the proportion was 200 to 1? In tubes 9 feet in diameter or larger with about ½ inch thickness of metal, the material becomes more homogeneous, and the internal strain would be less, or the initial strains and the stiffness would be different from what they are in a small tube like this. While I am not a believer in determining sizes by guess instead of by calculating, still I have been under the impression that a tube of 9 feet diameter and ½ inch in thickness would not remain circular under its own weight, and may even collapse.

PROF. BENJAMIN: I do not think these experiments have been carried far enough so that a man would be justified in staking his reputation on them by warranting them. It only shows the direction in which anybody can work to get results in a large number of cases.

In regard to steel, I am losing my faith in soft steel the more I experiment on it. I made some experiments this spring. A firm in this city gave me some steel plates all cut from one piece. I asked for steel that was a little harder than ordinary boiler plate. I took each plate and punched each end with the same punch so as to get two experiments. I pulled it apart under somewhat similiar conditions to those that would obtain if it were riveted to a frame. Then I reversed the plate and pulled apart the other end. There were a large number, I think 24 in all, that I pulled apart in that way, and nearly every one of them broke off with a crystalline fracture at one end, and a silky fracture at the other. It upset all my calculations. To settle the matter I took two drillings from the metal and submitted them to Prof. Smith for analyses. He could not find any difference in them.

MR. HERMAN: I experimented considerably lately with steel and have received remarkable uniformity of results from the same bars, in fact, to such an extent that Prof. Carpenter, of Cornell, who tested the same piece, expressed surprise at the uniformity in results. The reason I had the uniformity of results is that two specimens were annealed very carefully to the same temperature, and under the same conditions. I spoke about this at Meadville, and we compared figures on tests I have made with tests they had made. Their steel was not annealed, and mine was. They said that in the same piece annealed or naturally annealed steel in rolling and cooling will produce strains and conditions which will make specimens from the same piece look entirely different although they are perfectly identical mechanically.

PROF. LANGLEY: A few years ago I took a great deal of pains to make forty ingots to be used as standards of analyses. I had two men start up the mass in the furnace. I ran that out into ingots 5½ inches square on the face and when this came to be drilled there were no contiguous square inches that had the same composition. There was segregation in all of them. On the large ingots the segregation was so great that it amounted to having a totally different metal on the inside of the ingot than what you have on the outside of the ingot.

MR. JOHN WALKER: In Joliet we were making some machinery, and some of the machines were placed in the Fox Solid Steel Company, a very large factory where they are making cars, making the entire frames out of steel. The girths that came from the machines were very easily worked. All that came from those near the side and had been exposed to the atmosphere could not be punched at all, it broke the punches, and we thought the people had sent different kinds of steel.

It came to the simple-fact that after bending it had not been protected; but simply left carelessly in the outside atmosphere. If they had been kept in a protected place or away from rain or cold, they would have been punched as easily as they were on the outside. This is carrying the annealing process to a very fine point.

Mr. Searles: I would like to answer a question which was asked a little while ago in regard to the danger of large tubes collapsing under their own weight. The formula which answers the question is one we have here: P is the force applied on one point at the top of the tube which will strain it as much as it ought to be strained, because if you increase the force beyond that amount the tube will rapidly collapse. It will not do to use any more force than that, and practically only $\frac{1}{2}$ of that ought to be used. I figured out from a formula similar to this but in a little different shape, that a tube of nine feet diameter and $\frac{3}{8}$ thickness (rivited up, but assuming that the riviting was well done and that the lapping stiffened it as much as the rivit holes had weakened it,) the safe load, without distorting it too much or passing the elastic limit would be about 130 pounds per lineal foot. Then the elastic limit would be at 260 pounds, and if this weight were distributed over the entire semi-circumference it would be sixty per cent. more than that, or 416 pounds per lineal foot for the distributed load. I have seen a tube made of $^3/_{16}$th steel and five feet in diameter which, lying on its side, under its own weight, was not distorted enough so that it could be noticed by the eye that one diameter was greater than the other.

RECONSTRUCTION OF THE BURLINGTON BRIDGE.

By George S. Morison, Member, Western Society of Engineers.

[Read December 6, 1893.]

The bridge across the Mississippi River at Burlington, Iowa, was begun in the spring of 1867 and opened for traffic in July 1868. It was built by the Chicago, Burlington & Quincy R. R. Company, Mr. Max Hjortsberg, then Chief Engineer of that railroad being its Chief Engineer, and Mr. C. H. Hudson, now General Manager of the East Tennessee, Virginia & Georgia Ry., being the Resident Engineer; his assistant during construction was Mr. W. F. Merrill, now General Manager of the Chicago, Burlington & Quincy R. R.

It was the first iron bridge completed across the Mississippi River, the two earlier bridges, at Rock Island and Clinton, having wooden superstructures, only the draw of the Clinton Bridge being of iron.

As originally built the Burlington Bridge consisted of six spans of

250 feet each, east of the draw, a pivot draw 360 feet long, one span of 200 feet and one of 175 feet west of the draw, all measurements being between centers of piers. At the west end of the bridge the railroad curves to the north, and the two last spans were built on a curve. The foundations of the two west piers were put in with coffer dams and these piers rest directly on rock, this rock, however, being a firm shale. All the other piers had pile foundations the piles of the 3rd. and 4th. piers from the west, the latter being the pivot pier (hereafter called Pier VIII) being driven into the shale while the piles under the other piers stopped in sand. There are 324 piles under the pivot pier and from 133 to 160 piles under each of the other piers. All elevations were referred to a datum 100 feet below high water of 1851; the range between high and low waters was about 19 feet, the elevation of the low water of 1867, being given as 80.92. The piles were cut off at elevations varying from 75.7 or 5.2 feet below low water (Pier IV) to 64.75 or 15.15 feet below low water (Piers VII and VIII.) The piers were of masonry and were built on timber grillages two feet thick, which rest on the piles, all foundations being protected by riprap, which on the easterly piers was carried above low water. The stone came in part from Lemont, Ill., and in part from Mt. Pleasant, Iowa. The masonry was rock face work, of a somewhat rougher character than has since been used in bridges of the same class, and the thickness of the courses was very irregular.

The superstructure was built by the Detroit Bridge and Iron Works and was practically identical with that of the bridge at Quincy, Ill., which was building at the same time. The top chords of the fixed spans and the joint box connections at the foot of the posts were of cast iron, the posts were Phœnix columns, and the bottom chords were open loop bars; the design, howerer, would compare favorably with that of other bridges built at the same time. Both chords of the draw were of wrougnt iron and the draw was carried on a wrought iron drum and a heavy central cross girder, both drum and girder being of the box girder pattern; the only adjustment about the drum was in the six vertical rods by which weight was thrown upon the center, and by tightening or loosening these rods the division of weight between the center and the live ring, could be varied. The general design of the draw was better than that of the fixed spans and it did excellent service. The weakest feature of the superstructure was the attachment of the floor beams which were suspended from the pins by comparatively light hangers, which were subsequently reinforced.

The west bank of the river above the bridge is occupied by lumber yards which gradually encroached upon the river until a new shore line was formed east of the 175 feet span. In 1887 this span was removed and replaced by a solid embankment.

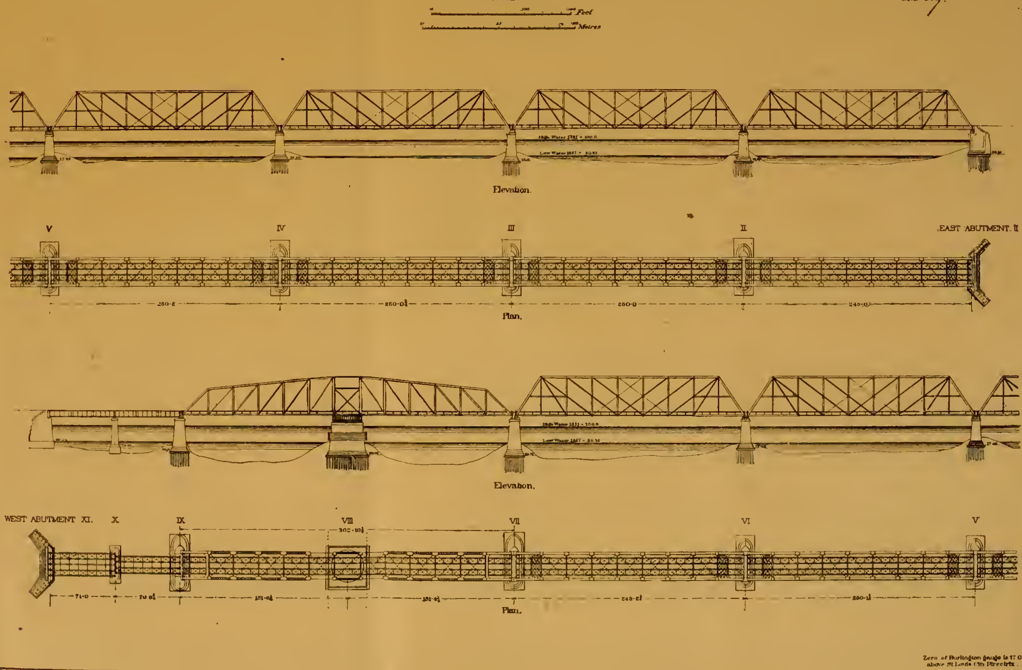
SHEET 1

C B & Q R R

BURLINGTON BRIDGE

General Elevation and Plan.

Scale



As an aid to navigation the Government had required a floating fender to be placed above the rest pier at the west end of the draw, which fender entirely closed the remaining span west of the draw, for all kinds of navigation.

In 1890, after this bridge had been carrying the heavy traffic of the main line of the Chicago, Burlington & Quincy R. R., for 22 years, it was decided to replace the old single track bridge with a modern double track structure and the charge of the work was placed in the hands of the author of this paper. He recommended that an entirely new superstructure be built, but that the existing piers should be altered so as to carry the double track superstructure. The two tracks on the new double track bridge were spaced 12 feet between centers and the axis of the bridge was shifted two feet upstream, the center of the new west bound track being eight feet and that of the new east bound track four feet from center of the old single track. At that time he thought that it would be expedient to close the remaining span west of the draw and replace it by a solid earth embankment: but as this required the consent of the General Government it was finally abandoned though this span was divided and shortened.

The piers as originally built had inclined ice breakers on the upstream side and semi-circular ends down stream: the shape of the piers was changed above high water to a rectangular section which carried the superstructure, the length of the rectangular section being the distance between shoulders of the lower portion of the piers. To adapt these piers to carry the new double track structure it was thought best to remove the entire upper portion of the pier; to carry the semicircular form at the lower end of the pier up to the bridge seat, and to take down the upper portion of the ice breaker and replace it with new masonry built with the same batter as the rest of the pier, thus shortening the length of the rake. With these changes the length of the piers on top was made long enough to carry a double track superstructure.

The trusses of the old superstructure were 15 feet, 9 inches between centers, those of the new superstructure, 28 feet, 6 inches, the old was a light single track superstructure, the new a heavy double track superstructure. The change therefore, involved doubling the weight to be carried by the pier and concentrating this double weight at points nearly twice as far apart as those which had carried the lighter weight: it was feared this might cause some yielding in the foundations at the two ends of the pier and crack the masonry. It was at first thought it might be necessary to put plate girders longitudinally on top of the pier, which would distribute the weight over the length of the pier: but on further thoughts it seemed to the engineaer that it would be simpler, cheaper and at least equally effective to convert each pier in-

to a girder by placing a steel tension member at the top, allowing the masonry to act as the compression member at the bottom as well as to perform all the functions of a web. The means adopted to accomplish this form the only novel feature of the work. The trusses are carried by heavy cast iron wall-plates which rest on the new coping of the masonry and which in every instance extend across the pier, one plate carrying two trusses. The masonry between the wall plates is built to the level of the top of the wall plates, special care being taken with the vertical joints. Four steel rods two inches in diameter were laid horizontally in a joint of the masonry and passed through both of the wall plates; screws were cut on the ends of these rods but the rods were not upset, the case being one in which change of length rather than strength was important. The wall plates were bedded on rust cement, and the masonry was laid in Portland cement mortar; when the whole was completed the rods were tightened in warm weather so as to be under strain under all conditions. Each wall plate is anchored by three anchor bolts 1¾ inches in diameter which extend into the second course below the coping. As thus arranged the pier is held by 12 inches of steel against all forces tending to open it at the top and the only effect of the weight of the superstructure will necessarily be to close the joints at the bottom. So, far, the arrangement, which is an inexpensive one, has given entire satisfaction. The details of this arrangement are given on Sheet 2.

The work of reconstruction was begun in July 1890, Mr. Elijah P. Butts being appointed Resident Engineer in charge of the work. The piers were renumbered from east to west, the east abutment being Pier I, and the pivot pier, Pier VIII.

The east abutment, which was a simple wing wall abutment, was taken down to below the surface of the ground, the foundation was extended and a new abutment was built in its place, the face of this abutment being made of Bedford limestone and the stone of the old work being used in the backing.

Piers II, III, IV, V, VI and VII were altered in accordance with the plans already described, the exact amount of new masonry as well as the outline of the original piers being as shown on Sheets 3 and 4. By cutting the upper portion of the pier down close to the wall plate bearings of the old trusses, it was possible to place the new coping and set the new wall plates before the old trusses were removed; the extension of the pier between the new wall plates could not be built and the steel rods could not be put in and screwed up until the old superstructure had been removed; as a matter of fact, it was not done generally till the new superstructure was erected. The new masonry was made entirely of Bedford limestone, laid in Portland cement, and the work was done by a force working under the immediate charge of the

C.B.&Q.R.R.

BURLINGTON BRIDGE

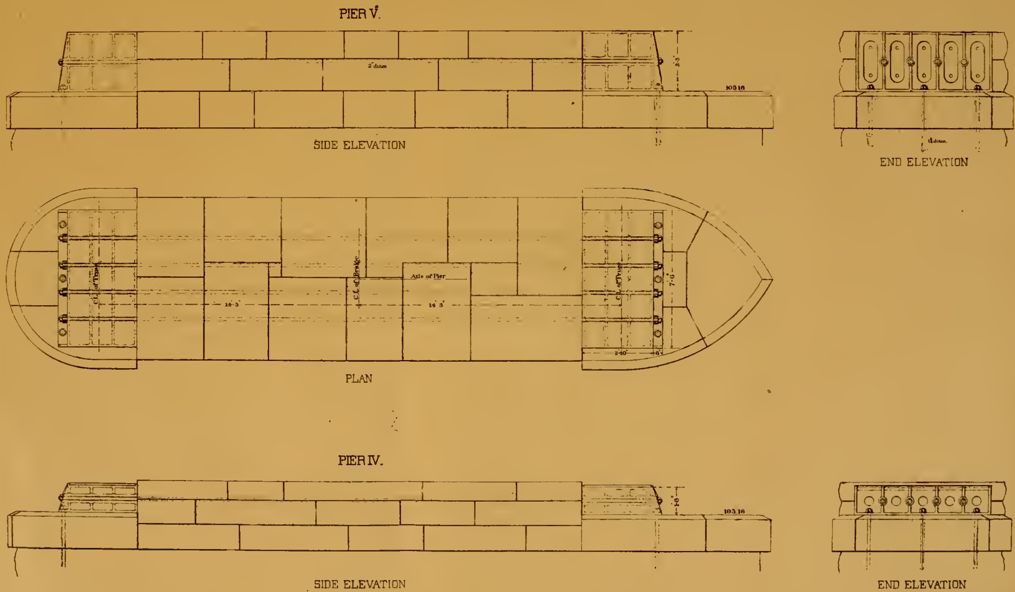
Arrangement of wall plates for double track bridge

Scale

0 5 10 Feet

0 1 2 3 Metres

Geo. S. Morison
Con. Engr.

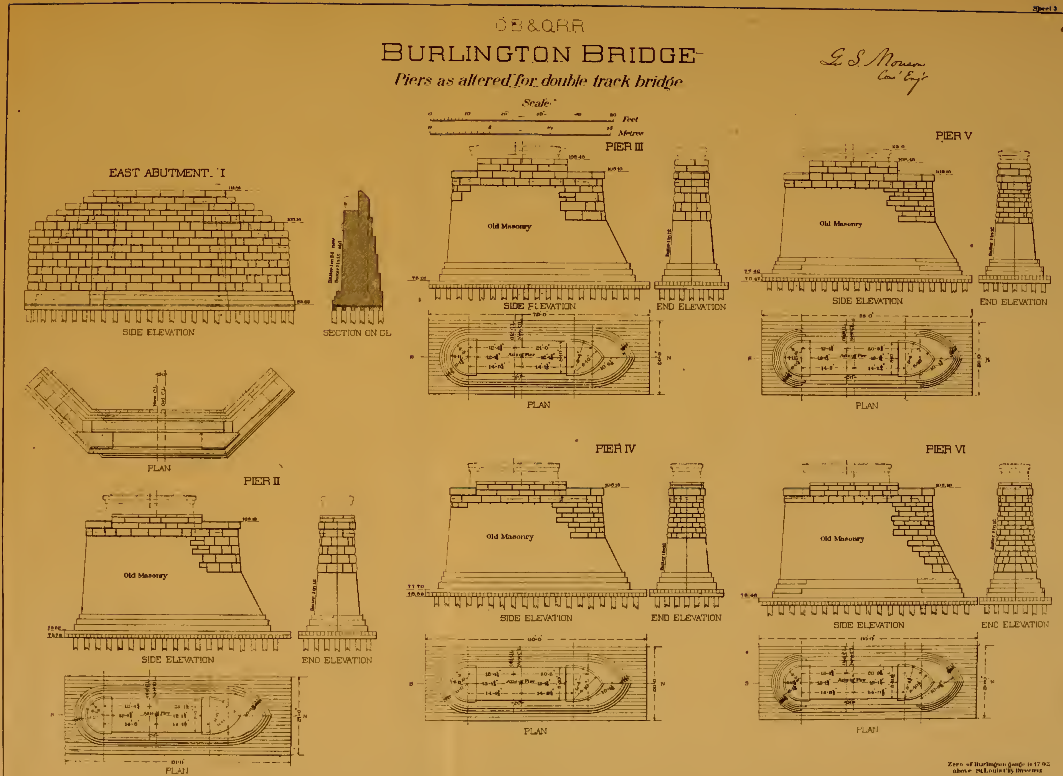


Zero of Burlington gauge is 17.05 above St. Louis City Directrix

C.B.&Q.R.R.

BURLINGTON BRIDGE

Piers as altered for double track bridge



Resident Engineer, there being no contract. The stones used in alterations were generally much heavier than those in the old piers and in several instances one course of new work corresponds to two courses of old work. In the case of Pier VI the greater portion of the upstream starling was rebuilt, the old masonry being in bad condition. The alteration of these piers was conducted without any serious difficulty of any kind and the material removed from the old piers was, for the most part, left around the piers where it serves as additional riprap.

The pivot pier (Pier VIII) required special treatment. This pier was originally built with a batter and was enclosed in a large timber crib nearly 400 feet long extending up and down stream, which served as the draw protection. When the bridge was first built this crib was carried up above high water and formed the fender for steamboats passing through the draw. When, however, the fender required renewal the crib was cut down to low water and a floating fender placed above it, an arrangement which was not as good as the original one. In reconstructing the bridge the original arrangement was restored. The turn table of the new draw is 30 feet 10 inches in diameter measured on center line of circular track; the smallest diameter of pivot pier which it was thought wise to put under this table was 34 feet, but this could be built plumb without a batter. The old pivot pier was 34 feet in diameter but built with a batter and the centers of the two pivot piers were two feet apart. The old pivot pier was cut down to such a height that the new plumb pier could be built upon it, the new masonry nowhere projecting more than three inches beyond the lower masonry. Above this point the new pivot pier was built as an entirely new structure, the outer ring being of Bedford limestone and the back of concrete. This work had to be done in winter when navigation was closed and the old draw had to be carried while the pier was altered. To accomplish this two wells were sunk to the masonry under the center posts of the trusses and carried down to the level at which the new masonry was to be started; in each of these wells was placed a column formed of cast iron blocks, each two feet high, which were placed one on another and then bolted together; the two columns when completed supported the cross girder immediately under the trusses. The drum was then cut out and entirely removed and the draw was left sustained on the two columns. The masonry was then removed to the desired height and the ring courses of the new pier built. When this was done the drum of the new turn table was set, and false work was driven in the two spans of the draw; everything then being in readiness the trusses of the old draw were removed and those of the new draw erected. The interior of the pier was filled with concrete and the work completed. A square timber

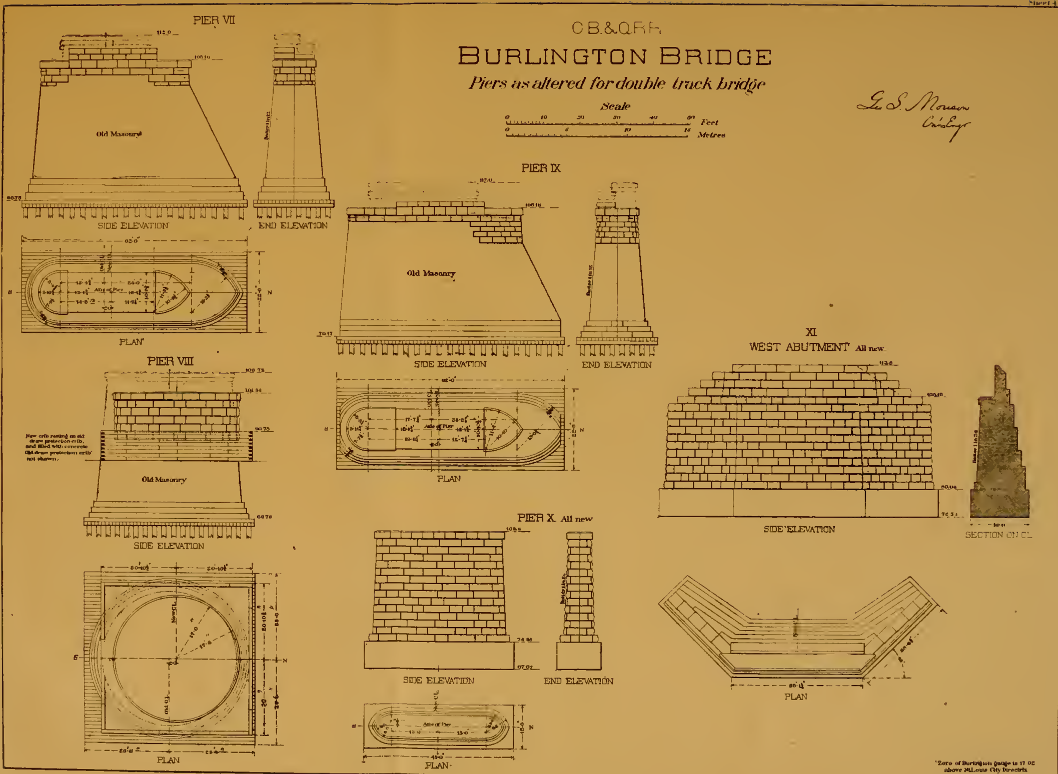
crib was placed around the pivot pier resting on the old fender crib and the space between this crib and the masonry filled with Portland cement concrete thus forming an additional bond between the old and the new work. Pier VIII is shown on sheet 4, which also shows the position of the square crib, though, as the fender crib is not shown, this crib appears entirely without the underworks which support it.

Unfortunately the work on this pier was attended by one very serious accident. On the morning of January 11, 1892, Mr. E. P. Butts, the Resident Engineer, while passing near the pier, which was then being dismantled, was struck on the head by a stone, receiving a fracture of the skull which proved fatal. No one saw the accident, but he was found unconscious under the pier. He had shown rare efficiency in the conduct of the work and his death was greatly regretted by every one who knew him. Mr. George A. Lederle succeeded him as resident engineer and completed the work.

As already stated it had first been proposed to close up entirely the span west of the draw, but it was afterwards thought best not to do so. A new abutment was built about forty feet east of the old pier and the space between this abutment and pier IX (west end of the draw) was divided by a new pier into two spans of seventy-one feet each. The new pier and abutment (X and XI) rest on the shale rock without piles, the foundations being put in with open coffer dams. These two piers are shown on Sheet 4. They are built of Bedford limestone, stone from the old piers being used as backing. Pier IX was altered in the same manner as the piers east of the draw.

The two short spans (IX-X and X-XI) are plate girders; the easterly span consists of four plate girders and the westerly of five, all spaced six feet between centers; the five girders were used to give additional width so that tracks can be laid leading to the south and connecting with the St. Louis, Keokuk & Northwestern R. R. leading to St. Louis which now forms a portion of the Burlington system.

There are no features about the superstructure which call for special consideration. There are six fixed through double track spans, each 246 feet long between centers of end pins, divided into nine panels of 27 feet 4 inches each, the trusses being placed 28 feet 6 inches between centers. The draw is 356 feet 6 inches long, consisting of 12 panels of 27 feet 4 inches and one central panel of 28 feet 6 inches. All the panels in the bridge are of the same length, except the central panel of the draw. The weight of the draw is distributed by four girders (which form the sides of a 28.5 ft. square) on eight equidistant points on a drum 30 feet 10 inches in diameter, and this drum rests on 63 cast steel wheels. Both lower and upper treads are of forged steel turned accurately to a true cone, the lower tread resting on a flat cast iron circle which is bolted to the masonry. A quarter size model of



Sheet 4
C.B.&Q.R.R.
BURLINGTON BRIDGE
Piers as altered for double track bridge
Scale
Feet
Metres
G. S. Morison
Ch. Engr.
PIER VII
Old Masonry
SIDE ELEVATION
END ELEVATION
PLAN
PIER VIII
New crib resting on old draw protection crib, and filled with concrete. Old draw protection crib not shown.
Old Masonry
SIDE ELEVATION
PLAN
PIER IX
Old Masonry
SIDE ELEVATION
END ELEVATION
PLAN
PIER X All new
SIDE ELEVATION
END ELEVATION
PLAN
XI
WEST ABUTMENT All new
SIDE ELEVATION
SECTION ON C.L.
PLAN
Zero of Burlington gauge is 17.02 above St. Louis City Directrix

this turntable, including the central panel, was exhibited by the manufacturers in the Transportation Building at the World's Columbian Exposition.

The six fixed spans and the draw are of open hearth steel and were manufactured in accordance with the requirements of the specifications which accompany this paper. The plate girders at the west end of the bridge are of wrought iron. The entire superstructure was manufactured by the New Jersey Steel & Iron Company of Trenton, N. J., from plans furnished by the Engineer of the bridge.

The superstructure was erected by a force working by the day under the immediate charge of the Resident Engineer. The draw is turned by an engine built by the Vulcan Iron Works of Chicago and designed, on lines suggested by the Engineer of the bridge, by Mr. James N. Warrington.

The superstructure is designed to carry a moving load of 6,000 pounds per foot of double track structure, this load being increased one half in estimating the variable effects of a moving load.

All parts which received a maximum strain from a load on a single track are proportioned on a basis of 4,000 pounds per lineal foot of track, increased to 8,000 pounds on a wheel base length of 20 feet. It will be observed that the weight taken per foot of track, when both tracks are loaded, is three-quarters the weight per track taken when only one track is loaded; this is equivalent to using a larger factor of safety on a single than on a double track, which the Engineer believes to be the correct practice.

The superstructure was completed and the double track put in service October 20, 1893. The work on the draw protection and some small details was not completed till December 14th, when everything was done.

The weight of the superstructure was as follows, the last coefficient being the weight per foot divided by length of span:

	Total Weight.	Weight per Foot.	Coefficient.
Six fixed spans........	4 937 987 lbs.	3 339 lbs.	13.58
Draw Span............	1 420 272 "	3 984 "	11.17
Plate Girders.........	306 383 "	1 955 "	27.93
Total............	6 654 642 "		

The cost of the entire work is given in the following table:

Pier I (East Abutment).........	$5 836.15
Pier II.........................	1 806.69
Pier III.........................	2 022.28
Pier IV.........................	1 996.79
Pier V.........................	1 586.09
Pier VI.........................	1 648.34
Pier VII.........................	1 467.77
Pier VIII, Pivot................	5 395.15
Pier IX.........................	1 641.69

Pier X, New	7 327.28		
Pier XI, New (West Abutment)	10 752.12		
Draw Protection	4 824.72		
Total Substructure		$46 305.07	
Span A, including erection	34 305.51		
Span B, " "	35 267.94		
Span C, " "	35 186.10		
Span D, " "	34 586.54		
Span E, " "	34 547.45		
Span F, " "	34 914.36		
Draw Span " "	77 898.00		
Plate Girders " "	12 495.42		
Painting	1 751.94		
Floor and Track	16 341.69		
Turning Machinery on Draw	8 245.52		
Telegraph Fittings	1 275.63		
Total Superstructure		$326 816.10	
Tools and Machinery		8 031.56	
Engin'ring, Salaries and Expenses		20 069 81	
Total Construction			$401 222.54
Less material from old spans sold			24 078.88
Net cost			$377 143.66

It will be observed that this is a striking illustration of the advances which have been made in bridge construction. The old single track Burlington Bridge, including approaches, cost about $1 250 000; it has been converted into a double track structure with an entirely new superstructure for less than one-third of the original cost.

C. B. & Q. R. R.

Specifications for New Superstructure of Bridge Across the Mississippi River at Burlington, Iowa.

I. GENERAL DESCRIPTION.

1. The superstructure will consist of six through spans each 246 feet long and one pivot draw, 356 feet 8 inches long; all built for a double track.

2. Each fixed span will be divided into nine panels of 27 feet 4 inches each; the trusses will be 41 feet between centers and spaced 28 feet 6 inches between centers.

3. The draw will be 356 feet 8 inches long between centers of end pins, the panels, except at center, being 27 feet 4 inches long and will be carried on a rim bearing turn-table 30 feet ten inches in diameter.

4. The draw will include the drum, turn-table, wheels, center and all structural parts connected with the same, the latching and lifting apparatus at the ends, the rack, two pinions, boxes and upright shafts reaching to engine platform about 21 feet above the rails.

Plans.

5. Full detail plans showing all dimensions, will be furnished by the Consulting Engineer. The work shall be built in all respects according to these plans. The contractor, however, will be expected to verify the correctness of the plans, and will be required to make any changes in the work which are necessitated by errors in these plans, without extra charge, where such errors could be discovered by an inspection of the plans.

II. MATERIAL.

6. All parts, except nuts, swivels, clev ses, wall pedestal plates, and some special parts of the turn-table and machinery of the draw, will be of steel. The nuts, swivels and clevises may be of wrought iron, but shall have sufficient strength to break the bodies of the members to which they are attached. The pedestal plates will be of cast iron.

7. All material shall be subject to inspection at all times during its manufacture, and the engineer and his inspectors shall be allowed free access to any works in which any portion of the material is made. Timely notice shall be given to the engineer, so that inspectors may be on hand.

Steel.

8. Steel will be divided into two classes: first, medium steel, which shall be used in all the principal truss members, the floor system, laterals, portals, transverse bracing and the lacing of the truss members: second, soft steel, which shall be used only for rivets and at the option of the contractor where wrought iron is permitted.

9. The coned wheels of the turn-table and the two principal pinions shall be of cast steel.

10. Steel shall be made by the open hearth process, but no steel shall be made at works which have not been in successful operation for at least one year.

11. All steel shall be made from uniform stock low in phosphorus, and the manufacturer shall furnish reports of the analysis of every melt, certified by a chemist satisfactory to the consulting engineer.

12. In the finished product of acid open hearth steel the amount of phosphorus shall not average more than $^{8}/_{100}$ of one per cent., and never exceed $^{1}/_{10}$ of one per cent.

13. In the finished product of basic open hearth steel the amount of phosphorus shall not average more than $^{6}/_{100}$ of one per cent., and never exceed than $^{7}/_{100}$ of one per cent.

14. A sample bar three-quarters of an inch in diameter shall be rolled from a four inch ingot cast from every melt. The first laboratory test shall be made on this sample bar in its natural state without annealing.

15. A second sample bar having a cross section of one square inch shall be cut from the finished product of every melt. The second laboratory test shall be made on this sample bar in its natural state without annealing.

16. In the laboratory tests all observations as to elastic limit, ultimate strength, elongation and reduction shall be made on a length of eight inches.

17. A piece of each sample bar shall be bent 180 degrees, and closed up against itself without showing any crack or flaw on the outside of the bent portion.

18. The first laboratory test shall meet the following requirements:

	Medium Steel.	Soft Steel.
Minimum Ultimate Strength, pounds per square inch	65 000	57 000
Minimum Elastic Limit, pounds per square inch	38 000	32 000
Minimum Percentage of Elongation in 8 inches	20	28
Minimum Percentage of Reduction at Fracture	40	50

19. The second laboratory test shall meet the following requirements:

	Medium Steel.	Soft Steel.
Maximum Ultimate Strength, pounds per square inch	72 500	63 000
Minimum Ultimate Strength, pounds per square inch	64 000	55 000
Minimum Elastic Limit, pounds per square inch	37 000	30 000
Minimum Percentage of Elongation in 8 inches	22	28
Minimum Percentage of Reduction at Fracture	44	50

20. If the ultimate strength comes within five hundred pounds of the maximum or minimum limit, a second test will be made, and both tests will be required to come within the limits.

21. Every melt which does not conform with these requirements shall be rejected. Cases in which the tests are thought not to give fair representation of the character of the material shall be referred to the Consulting Engineer.

22. A full report of the laboratory tests shall be furnished, certified by an inspector accepted by the Consulting Engineer.

23 The broken and bent specimens shall be preserved subject to the orders of the Consulting Engineer.

24. Three notices of the acceptance of each melt shall be mailed on the day of such acceptance, stating the number of the accepted melt and quality of steel. Two of these notices shall be sent to the Consulting Engineer at his Chicago and New York offices respectively, and one to the shop inspector at the works.

25. Analyses shall be made by the manufacturer of every melt, showing amount of phosphorus, carbon, silicon and manganese, and certified copies of these analyses shall be furnished to the Mill Inspector, who will forward them to the Consulting Engineer. The phosphorus and carbon analyses shall always be made. Analyses for silicon and manganese shall be made whenever called for by the Inspector. Copies of all analyses, whether made by request of the Inspector or by the desire of the manufacturer, shall be furnished to the Consulting Engineer.

26. Weekly reports in full detail, including reports of chemical analyses, shall be sent to the Consulting Engineer at his Chicago office not later than the end of the week succeeding the week in which such tests are made.

27. Three notices of the shipment of manufactured material, identifying the melts and dimensions, shall be mailed on the day after such shipments are made, in the same manner as the notices of acceptance of material.

28. Every finished piece of steel shall be stamped on one side near the middle of the bar, and also on both ends of the bar, with a number

identifying the melt. If it is found impossible to stamp any particular piece on the ends, the Inspector may authorize the two end stamps to be put on the surface, within one-half inch of each end, the fact of the stamping being done in this way to be specified distinctly on all notices and invoices; this may be done, however, by an agreed character.

29. The finished product shall be perfect in all parts and free from irregularities and surface imperfections of all kinds.

30. The cross sections shall never differ more than two per cent. from the ordered cross sections as shown by the dimensions on the plans.

31. All sheared edges shall be planed off so that no rough or sheared surface shall ever be left on the metal.

32. Steel for pins shall be sound and entirely free from piping. All pins in the main trusses shall be annealed before they are turned and shall be drilled through the axes.

Cast Steel.

33. A sample bar 1¼ inches in diameter and 16 inches long shall be cast from every melt. This sample bar shall then be turned down to three-quarters of an inch in diameter and the laboratory tests made on it.

34. These laboratory tests shall show an ultimate strength of at least 70,000 pounds, an elastic limit of at least 40,000 pounds, and an elongation of at least 15 per cent. in eight inches and a reduction of 18 per cent at point of fracture.

35. Steel castings shall be sound and as free as possible from blow holes.

36. If on the finished surface the blow holes cover more than $\frac{1}{10000}$ part of the entire surface, and if any blow hole exceed one-eighth of an inch in diameter, the casting shall be rejected.

Cast Iron.

37. Cast iron shall be the best quality of dark gray charcoal iron of a quality suitable for car wheels, the castings to be entirely sound and free from blow holes.

III. MANUFACTURE.

38. The work shall be done in all respects according to the detail plans furnished by the Consulting Engineer.

39. Where there is room for doubt as to the quality of work required by the plans or specifications, the doubt shall be decided by using the best class of work which any interpretation would admit of.

40. All workmanship, whether particularly specified or not must be of the best kind now in use. Past work done for the same Consulting Engineer will never be recognized as a precedent for the use of other than the best kind of work.

41. Ragged edges of any kind of irregularities or unnecessary roughness will be sufficient ground for rejection.

42. All surface in contact shall be cleaned and painted before they are put together.

43. All work shall be finished in the shop and ample time given for inspection.

44. No material shall be loaded on cars until accepted by the inspector.

45. The finishing of work after loading will not be permitted.

Riveted Work.

46. All plates, angles and shapes shall be carefully straightened at the shops before they are put together. Mill straightened will not be considered to meet this requirement.

47. All riveted members shall be drilled, except as provided below.

48. If the rivet holes are marked from templets, these templets shall lie flat without distortion when the marking is made.

49. In metal not more than $\frac{3}{4}$-inch thick, the rivet holes may be punched with a punch at least $^{5}/_{32}$ of an inch smaller than the diameter of the rivets as given on the plans, and working on a die only $^{1}/_{64}$ of an inch larger than the punch.

50. The several parts of the member shall then be assembled and the holes drilled out so that at least $^{1}/_{16}$ of an inch of metal is everywhere taken out.

51. After the drilling is completed a special reamer shall be run over both edges of every hole, so as to remove the sharp edges and make a fillet of at least $^{1}/_{16}$ of an inch under each rivet head.

52. The assembled parts shall then be riveted up without taking apart, unless specially directed by the Consultng Engineer.

53. In general, all holes which are to pass through several thicknesses of metal shall be drilled with all these pieces of metal assembled in the exact relative position they are to hold in the bridge.

54. The size of the rivet shown on the plan is the size of the cold rivet before heating.

55. The diameter of the finished hole shall not be more than $^{1}/_{16}$ of an inch greater than the diameter of the cold rivet. It is intended that the heated rivet shall not drop into the hole, but require a blow from the hammer to force it in. If it is found that the rivets will drop easily into the holes the inspector shall condemn those rivets and order a larger size.

56. In all cases where riveting is to be done in the field, the parts so to be riveted shall be fitted together in the shops and the rivet holes drilled while they are so assembled.

57. An iron templet not less than two inches thick, may be used instead of the floor beams when drilling the holes in the posts, and the same templets instead of the posts when drilling holes in the floor beams; a similar templet may be used in the same manner in drilling the connections between the floor beams and the stringers.

58. All rivets shall be driven by power wherever this is possible.

59. All rivets shall be regular in shape, with hemispherical heads concentric with the axis, absolutely tight and shall completely fill the holes. Tightening by calking or recupping will not be allowed. This applies to both power driven and hand driven rivets.

60. All pin holes and holes for turned bolts passing through the whole width of a riveted member shall be bored or drilled after all other work is completed.

61. All end surfaces in contact shall be carefully faced, the facing to be done after the entire member is assembled and riveted up.

62. When four cord piecesare fitted together complete in the shop there shall be no perceptible wind in the length of the four sections.

63. All chord sections shall be stamped at each end on the outside with letters and numbers designating the joints in accordance with the diagram plan furnished by the Consulting Engineer.

64. Pin holes shall be bored truly and at exact distances parallel with one another and at exactly right angles to the axis of the member.

65. Pin holes in the posts shall be truly parallel with one another and shall be at right angles to the axis of the post.

66. Pin holes shall be bored with a sharp tool which will make a clean smooth cut. Two cuts shall always be taken; the finishing cut never to be more than $\frac{1}{8}$ inch. Roughness in pin holes will be sufficient reason for rejecting a whole member.

67. Measurements shall be made from an iron standard of the same temperature as the member measured.

68. The angles of stringers must be square and straight. The web plate must not project above the angles and the top surfaces of the top angles must be such that the outside edges are never above a true plane and never more than one-sixteenth of an inch below a true plane coincident with the root of the angles.

69. The outside angle at the root of the angles connecting the stringers with the floor beams or the floor beams with the posts, chords or other members, shall never be less than a right angle and the excess over a right angle shall never be greater than $\frac{1}{8}$ of an inch in the longer leg of the angle; the angle shall be perfectly straight.

70. In fitting these angles to stringers or floor beams they shall be so fitted that the exact length is measured to the root of the angle, the two roots being in exactly the same plane; the entire end of the assembled member shall then be faced. The effect of these requirements will be to prevent any reduction of area of the angle at the root by facing and to secure a true surface of the whole width of the connection which will require no strain in the rivets to draw the parts together.

71. All bearing surfaces shall be truly faced.

72. All sheared edges shall be planed off and all punched holes shall be drilled out so that none of the rough surface is ever left upon the work.

Forged Work.

73. The heads of eye bars shall be formed by upsetting and forging into shape by a process acceptable to the Consulting Engineer. No welds will be allowed.

74. After the working is completed the bars shall be annealed in a suitable annealing furnace by heating them to a uniform dark red heat and allowing them to cool slowly.

75. The form of the heads of the steel eye bars may be modified by the contractors to suit the process in use at their works, but the thickness of the head shall not be more than $^1/_{16}$ inch greater than that of the body of the bar, and the heads shall be of sufficient strength to break the body of the bar.

76. The heads and enlarged ends for screws in laterals, suspenders and counters shall be formed by upsetting and shall be of sufficient strength to break the body of the bar.

77. Nuts, swivels, and clevises, if made of steel, shall be forged without welds: whether made of steel or wrought iron, one of each size shall be tested and be of sufficient strength to break the bars to which they are attached.

78. Eye bars shall be bored truly and at exact distances, the pin holes to be exactly on the axis of the bar and at exactly right angles to the plane of the flat surfaces.

79. When six bars of the same billed length are piled together the two pins shall pass through both pin holes at the same time without driving. Every bar shall be tested for this requirement.

80. Pin holes shall be bored with a sharp tool that will make a clean, smooth cut. Two cuts shall always be taken, the finishing cut never to be more than $\frac{1}{4}$ inch. Roughness of pinholes shall be sufficient reason for rejecting bars.

81. Twenty full-size steel eye bars shall be selected from time to time from the bars made for the bridge, by the inspector for testing.

82. No bars known to be defective in any way shall be taken for test bars, but the bars shall be selected as fair average specimens of the good bars which would be accepted for the work.

Machine Work.

83. All bearing surfaces shall be faced truly.

84. Chord sections shall be faced after everything excepting the projecting splice plates is riveted up complete, the facing to be perfectly true and square.

85. The ends of the stringers and of floor beams shall be squared in a facer.

86. All surfaces, so designated on the plans, shall be planed.

87. All sheared edges shall be planed off and all punched holes shall be drilled or reamed out.

88. All pins shall be accurately turned to a gauge, and shall be of full size throughout.

89. Pin holes shall be bored to fit the pins with a play not exceeding $^1/_{50}$ of an inch. These requirements apply to lateral connections as well as to the other pins.

90. The plans show the difference between the centres of pin holes. Shop measurements, however, shall be made between the bearing edges of tension members, with a proper allowance for the diameter of the pin. An iron standard of the same temperature as the piece measured shall always be used.

91. All screws shall have a truncated V thread, United States standard sizes.

92. The rail plates shall be planed on the bottom after being riveted up, then planed on the top and the surface polished. Any roughness or irregularity which prevents a uniform opening between the rail heads shall be planed out.

93. The rollers shall have the hollow sides planed, and the bearing surfaces turned to a perfectly true cylinder and polished.

Miscellaneous.

94. All material shall be cleaned, and if necessary, scraped, and given one heavy coat of Cleveland iron-clad paint, purple brand, put on with boiled linseed oil, before shipment. This applies to everything except machine finished surfaces.

95. The same paint shall be used wherever painting is required.

96. All machine surfaces shall be cleaned, oiled and given a heavy coat of white lead and tallow before shipment. The inspector must see that this is a substantial coat such as is used on machinery, and not a merely nominal covering.

97. All small bolts, all pins less than six inches in diameter, the expansion rollers and everything with special work on it, shall be carefully boxed before shipment.

IV. INSPECTION.

98. The mill inspection shall be performed at the expense of the contractor, by an inspector accepted by the Consulting Engineer.

99. This inspector will be required to furnish the certificates and notices in the manner specified above.

100. The mill inspector shall from time to time check the manufacturers' analyses by analyses made by an independent chemist.

101. The acceptance of material by such inspector will not be considered final, but the right is reserved to reject material which may prove defective or objectionable at any time before the completion of the contract.

102. The inspection at the shops will be under the charge of an inspector appointed by the Consulting Engineer, with such assistance as may be required.

103. Such inspector will be considered at all times a representative

of the Consulting Engineer, and his instructions shall be followed in the same manner as if given by the Consulting Engineer.

Tests of Full Sized Bars.

104. The tests of full-sized eye bars shall be made in the large testing machine at Athens, Pa., unless some other machine is specially accepted by the Consulting Engineer.

105. These bars will be required to develop an average stretch of twelve per cent., and a minimum stretch of ten per cent. before breaking. The elongation shall be measured on a length of not less than twenty feet including the fracture.

106. The bars will be required to break in the body.

107. They shall also show an elastic limit of not less than 32,000 lbs., and an ultimate strength of not less than 60,000 lbs., as indicated by the registering gauges of the testing machine at Athens.

108. In cases of bars too long for machine, the bars shall be cut in two, each half reheaded, and both halves tested in the machine, the two tests, however, to count as a single test bar.

109. In these tests, a failure to meet the required elongation will be considered fatal and be a sufficient cause for condemning the bars represented by the bars so tested, but the Consulting Engineer shall examine carefully into the cause of the breakage of any bar which does not meet the requirements, and may order additional tests if he sees fit.

110. The failure of a bar to break in the body shall not be considered sufficient reason for rejection, provided the required elongation is obtained and not more than one-quarter of the bars break in the head.

111. In all requirements and tests the quantities given are minimum or maximum requirements and not averages unless expressly so stated.

V. TERMS.

112. The work will be paid by the pound of finished work loaded on cars and delivered to the Chicago, Burlington & Quincy Railroad at Chicago.

113. No material will be paid for that does not form a part of the finished structure.

114. The contractor will be required to furnish the field rivets for erection, furnishing 20 per cent. in excess of each size over and above the number actually required, but this excess will not be estimated, but considered as taking the place of the work which is not done on these rivets.

115. Prices will be per pound of finished weights at separate rates for the fixed spans and for the draw.

116. The first fixed span shall be delivered complete in Chicago on or before October 1, 1890; the second span on or before November 1, 1890; the third span on or before December 1, 1890.

117. The fourth span shall be delivered in Chicago on or before June 1, 1891; the fifth span on or before July 1, 1891, and the sixth span on or before August 1, 1891.

118. The draw shall be delivered on or before December 1, 1891.

119. Approximate estimates shall be made at the end of each month of the material received and work performed up to that time.

120. In these estimates material received at the shops, but not manufactured, shall be estimated at 60 per cent. of the contract price for finished material.

121. Material manufactured but not shipped shall be estimated at 80 per cent. of the contract price.

122. Material completed and shipped shall be estimated at the full contract price.

123. Payments shall be made on these estimates on or about the middle of the following month, deducting therefrom 10 per cent., which shall be held as security until the completion of the entire contract.

124. In these monthly estimates no material will be estimated as received at the shop more than five months before the date set for the completion and shipment of such material.

125. In these monthly estimates no material will be estimated as manufactured more than three months before the date set for the completion and shipment of such material.

126. The contractors will be required to keep the material at their shops insured from injury by fire to the full amount of the payments made on such material by the Railroad Company.

CHICAGO, May 1, 1890. GEO. S. MORISON,
Consulting Engineer Burlington Bridge.

THE FERRIS WHEEL.

BY WM. H. SEARLES, MEMBER, CIVIL ENGINEER'S CLUB OF CLEVELAND.

[Read November 14, 1893.]

The most conspicuous object that greets the eye of the traveler as he approaches the grounds of the Columbian Exposition from the south, or upon the elevated railroad from the north, is the now world renowned Ferris wheel. Its great circles described by day magnificent ellipses upon the sky, or by night shining with their myriad electric lights, they appear like a galaxy of stars. Not even the domes of the finest buildings on the grounds show to such advantage from a distance. In fact, as one watches the domes from the windows of an elevated car, they seem to pass one by one through the circle of the wheel which, for the moment, surrounds them like a halo. As one moves from a southerly to a westerly point of view, the great wheel appears to pass through all the phases possible to it of the circle, ellipse and straight line. On a nearer approach one is struck by the slow and majestic motion of the wheel as it carries its load of living freight silently and steadily through its great orbit.

But it is not to the esthetic qualities of the wheel that I would call your attention particularly at this time. We are more concerned in the design of this structure as a work of engineering, and in the method of its erection. No complete description has been given to the public by the designers. On the contrary, when applied to, they have politely declined to furnish very much information. This paper, therefore, is not to be regarded as a report from the engineers, although it is believed to be accurate in its details, or very nearly so.

The diameter of the wheel is 250 feet. It consists of a regular pin-

connected girder which returns into itself to form a circle. Like a bridge it has two parallel trusses, and these are connected by horizontal struts between the inner chords, but unlike a bridge, there is no connection between the chords which form the outer circle. There is, however, a second system of horizontal struts between the radial posts which connect the inner and outer rims. These struts are placed 15 feet from the outer circumference and are attached to the posts by solid knee-brace connections. The cars, suspended from the pins of the outer rim, swing freely between the trusses, and clear of the last mentioned struts. The circle is divided into 36 panels. The chord members of a single panel are straight, the outer chord being much the heavier of the two. It is composed of steel web plates 24 inches wide with a top plate 26 inches wide, and angles 4 inches by 4 inches; and lattice bars on the fourth side. The radial posts are 35 feet long, center to center, composed of channel bars latticed. The horizontal struts already mentioned are of channels latticed with a section of 9 inches by 9 inches. The pins used in the outer chords are of 5½ inches in diameter. The passenger cars are 24 feet long, 13 feet wide and 10 feet deep at the center, the roof being somewhat arched. Each car contains 38 circular seats placed in four rows and allowing standing room between them, so that the maximum number of passengers is sixty. The width of the wheel is 28 feet out to out, and a little less than 26 feet in the clear. The sway bracing used between the struts is composed of square rods, as also is the diagonal bracing in the panels.

The grand rim is suspended from the axle by two sets of rods. The first set extends in pairs to each pin of the inner chord ; the second set parallel to the first, extends to each pin of the outer chord. All of these are attached to the hubs or spiders of the axle. The third set of rods pass diagonally from the spider near one end of the axle to the inner pins of the opposite truss, crossing each other midway. The spiders are 35 feet apart, while the mean width of the rim is 27 feet, consequently the rods are somewhat inclined to the plane of the wheel; and those connected with the outer rim being parallel to the radial posts, are necessarily bent at the inner rim so that, when under strain, they produce some tension in the horizontal struts. The suspension rods are inactive toward the extreme upper part of the wheel, and the entire wheel is sustained by the rods in the lower half. The several systems of diagonal bracing provide against wind strains on the sides, and also serve to keep the wheel in a true plane relative to itself as to warping, and to maintain the plane perpendicular to the axis during revolution. All rods are furnished with turn-buckles so that adjustment can be carried to any desirable extent. The truss being designed for a true circle and constructed originally in that shape, is kept in the same by the adjustment of the suspending rods, except the crown of the wheel, where the rods, of course, are inert. The latter portion of

the wheel acts, therefore, as an arch, all the thrust of which is taken up at once by the radial rods inclined to the vertical.

There is some likeness in this wheel to the ordinary bicycle wheel, with some differences. The bicycle wheel has a continuous rim, whereas this is pin-connected and depends upon its truss form for stiffness. The bicycle wheel carries its load at the axle, which is supported by the upper half of the rim, and the rim is supported at but one point on the ground. The Ferris wheel receives its support from the axle and carries its load at thirty-six points of the circumference. Relatively, therefore, the Ferris wheel is less severely taxed than the bicycle wheel on account of its distributed load and its freedom from jars and concussions. The load on the lower half tends to stability, while the load on the crown tends to deform the arch. But whatever the span of this arch may be, it is relatively small compared with the depth of the truss, which is thirty-five feet. The truss serves a further purpose of affording stability against wind pressure, and this, of course, is necessary on all parts of the wheel, including the crown. The inner chord is thus seen to take all of the wind strain and a part of the load.

Each panel covers ten degrees, so that the length of a member in the outer rim is about 21 feet, 10 inches, and in the inner rim 15 feet, 8½ inches.

The shaft upon which the whole wheel revolves is 33 inches in diameter and 45½ feet long, the largest forged steel shaft in the world. It was forged hollow and has a bore of seventeen inches. The shaft proper weighs 93,000 pounds. The spiders, which are of cast-iron, weigh 47,500 pounds. The shaft has end journals, 4 feet long by 30 inches in diameter. These rest in pillow blocks which weigh 36,200 pounds. The towers on which the latter rest are rectangular in plan, and at the surface of the ground are 50 by 35 feet, the longer dimensions being at right angles to the plane of the wheel. Their height from the ground is 140 feet. They are built of inclined posts and horizontal struts, which are composed of latticed channel bars in the usual manner of bridge construction, and tied together with diagonal rods in all directions. They are further stiffened near the ground by plate iron arch girders, which serve also to give an architectural effect to the structure. Each leg of either tower rests upon a concrete foundation 20 feet square and 35 feet deep, and is anchored to steel bars imbedded in the mass. The pits for the foundations were excavated partly through quicksand, and the work being done in the winter, steam was used to keep the concrete from freezing until it could set. After the completion of the towers it was necessary to raise the axle to the height of 140 feet and place it in its bearings. The lower panel of the wheel was then put in place upon suitable supports and connected to

the spiders by radial rods; other panels were then added on either side, suitable scaffolding being carried up as the wheel progressed, until finally the last panel was put in place like a keystone at the crown. All the radial and diagonal rods having been put in place as the work progressed, it only remained to adjust the length of these after the wheel was swung free of its supports.

To provide for the motion of the wheel, sprocket-plates of cast-iron were riveted to the outer rim, the plates being segmental on their outer edge so as to form a perfect circle. These plates are 3½ inches in thickness, and are riveted to the wheel by three rows of rivets of about 16 inches pitch. Semi-circular notches 24 inches apart were made in the outer edge of these cast plates to receive the pins of the driving chains; the pins are 14 inches long by 5½ inches in diameter. For links the chain has small eye bars in pairs 24 inches long. Each pin carries also a pair of rollers 10 inches in diameter by 2 inches thick, which serve to support the chain upon a curved trough under the wheel and keep it in positive contact with the sprocket plates while the chain is passing from the idler to the driving sprocket wheel, a distance of 16 feet. The chain engages the wheel on its lower periphery for a distance of about 10 feet. The driving wheels are 9 feet in diameter, and keyed to a shaft 18 inches in diameter.

The power for giving motion to the wheel is supplied by a pair of horizontal engines connected to one shaft by cranks at right angles. The cylinders are 30 inches in diameter by 48 inches stroke. The valves are moved by ordinary link motion. There is, however, a steam reversing gear.

There are two shafts in the system between the engine shaft and the sprocket wheel shaft. The first of the intermediate shafts is vertical and is connected with the engine shaft by helical spur wheels, 20 inches wide inside of the shrouding. The other shaft carries pinions 28 inches wide inside of the shrouding with teeth of six inch pitch working into spur wheels of 10 feet diameter on the sprocket wheel shaft. On the third shaft is also keyed the brake-wheel which has a plain band-brake, operated by a Westinghouse air brake using 60 pounds pressure per square inch. This serves to control the great wheel through the chain, and to hold it in position when motion is not desired. The motion of the wheel is smooth and noiseless save for the clinking of the chain rollers. The wheel makes one revolution in nine minutes. The motion is reduced about five hundred times from the engine to the main wheel. If we suppose a mean effective pressure of sixty pounds in the cylinder, and a piston speed of four hundred feet per minute, we should have 2,000 effective horse-power at the engines.

The weight of the wheel proper, excluding turn-buckles, is	1,203,996 lbs.
Of the cast sprocket-plates	317,000 "
Of the axle and spiders	140,500 "
Of thirty-six cars at 26,000 lbs. each	936,000 "
And of turn-buckles, etc., say	10,000 "
Making a total of dead weight in motion of	2,607,496 lbs.

The maximum live load, estimated at sixty passengers per car at 140 pounds per passenger, is 302,400 pounds, and this added to the dead weight makes a grand total of 2,909,896 pounds. The engines are required to overcome the inertia of this mass and the friction of the axle and gear.

There is, furthermore, to be considered the effect of unequal loading of the cars, and the action of the wind which would be greater at the top of the wheel than at the bottom by some unknown amount. The unequal loading evidently plays but a small part in relation to the action of the wheel. If one-half of the wheel were completely loaded with passengers and the other side empty we would have 157,200 pounds to be raised by the engine power. The radius of the center of gravity of the semi-circle reduces the lever arm of this live load to 42 per cent. of the wheel radius, so that with a motion of the periphery of 90 feet per second, it would require only about 180 horse-power, or, allowing 10 per cent. for friction, say 200 horse-power additional to that necessary to move the dead load of the wheel. The effect of high winds upon the rotation of the wheel would be much more serious than this, especially as the surrounding buildings protect the lower part of it.

The engines are located upon the center line of the wheel, and the shafting extends right and left so as to gear with the sprocket shafts for each truss. The engine shaft is 20 inches in diameter with 18 inch journals.

The weight of the steel in the anchorages is	57,805 lbs.
The weight of the iron and steel in towers, excluding turn-buckles, is	585,988 "
The weight of pillow-blocks on top of towers	36,200 "
Making a total fixed weight of iron and steel of	680,038 lbs.

The success of the Ferris Wheel, both as a structure and as a machine, has been amply proved in the experience of the past summer. It has withstood, without injury, a number of gales, one of which at least, was of extreme violence. Financially its success has been phenomenal. The largest number of passengers

carried in one day was 34,451. Total number for the season of twenty weeks, 1,500,000.

The wheel proper was constructed for the company by the Detroit Bridge and Iron Works. The cast-sprocket-plates were furnished by the Walker Manufacturing Company of Cleveland. The driving chains came from the Keystone Bridge Company of Pittsburg. The engines were built by William Todd & Co., of Youngstown, Ohio; and the great axle was forged by the Bethlehem Iron Company of South Bethlehem, Pa., using the enormous steam hammer, a full-sized model of which was exhibited in the Transportation Building. This hammer is 90 feet high by 38 feet broad and weighs 2,386 tons. The striking weight is 125 tons. It is only by the use of such massive tools that the Ferris Wheel became a possibility.

DISCUSSION.

President A. H. Porter: Gentlemen, the Ferris Wheel has excited much interest all over the world and among all intelligent people, and especially among engineers of all classes. We recognize the difficulty that Mr. Searles has labored under in getting the information desired. The subject is now open for discussion. I presume that many of the members have information which Mr. Searles was unable to obtain.

Prof. J. W. Langley: In conversation with Mr. Ferris I understood him to say that the total engine power was 4,000 horse-power, of which 2,000 were idle and 2,000 active.

Mr. Searles: The estimate that this engine had 2,000 horse-power is quite in accord with this statement.

Mr. Charles F. Lewis: If I remember rightly these suspension rods, when they were first placed in the wheel, were single; they were not trussed. Afterwards, when I saw the wheel in August, a great many of these rods were trussed. I think this was explained here a couple of months ago by Mr. Walker. Mr. Searles did not mention that. Mr. Ferris had more or less trouble with the suspension rods, especially those that were in the center, and he took that method of doing away with it.

Mr. Searles: I confined myself mostly to simple description and tried to avoid speculation in regard to the wheel. I think that speculation may now be in order. Many of the views entertained by Mr. Ferris will bear discussion, although they might be a little out of place in the paper.

Mr. W. R. Warner: I happen to know a little something about the speculation. Those who have entered into it from that standpoint have made well out of it. The wheel paid for itself entirely before

the Fair was half over, so I suppose it was a splendid speculation.

MR. A. H. PORTER: Little cards will be distributed here this evening which will tell the total number of passengers carried up to the first of November. The total number is 1,740,000. The weights of the several parts are also given.

MR. SEARLES: True weights were never given out until I obtained them from Mr. Gronau.

MR. J. W. WILLARD: In the paper read by Mr. Searles of the trial trip of the wheel, I did not catch the idea whether the entire 36 cars were put in place or whether only 6 cars.

MR. SEARLES: The first revolution was made without cars. The men were all over the frame work hanging on as best they could, seated in the trusses. Then when they took the first passengers, there were only six cars attached at different points of the circumference.

MR. G. E. GIFFORD: We lose sight, perhaps, of the fact which has made this wheel a success, and that is its workmanship. We had a little discussion of it at our office recently, and the question was raised as to whether it required greater skill to complete a wheel like that than to complete a little Swiss watch; we decided in favor of the wheel. You cannot feel a jar, and you cannot feel the wheel stop; and we came to the conclusion that there was some very skillful workmanship put on that wheel.

MR SEARLES: I would like to call the attention of the members of the club to the extreme narrowness of the wheel compared with the diameter, as seen in the cross-section. I have never seen such a view published, and I was surprised to see how extremely slender the column appears. Seeing the wheel in perspective and other views, we do not realize how narrow it is compared with its diameter, and the small angle the diagonal rods have to make with each other as against wind pressure. I would suggest that the question is not merely as to wind pressure on the side of the wheel, but wind blowing along the plane of the wheel, and tending to deform the circle, throwing it somewhat into elliptical form. All these cars present a flat surface to the wind and therefore act like sails.

A full discussion of the strains of the wheel would require considerable time. A good many suppositions, I think, would have to be made before we should have covered all the ground of the various circumstances that may arise in the experience with the wheel.

MR. C. O. PALMER: I would ask Mr. Searles if he knows how they raised the axle.

MR. SEARLES: I have no details of it.

MR. AMBROSE SWASEY: Speaking of what Mr. Searles has said about Mr. Gronau's statement, that all tie-rods, with the exception of the top

one, were in tension all the time, I remember going over the wheel quite early after it was put up, and I remember that the rods near the top—say five or six each side of the center—were very loose ; in fact, swaying a great deal, and it seemed to indicate that they were anything but in tension, although theoretically, they might have been, under Mr. Gronau's calculations; but it seemed, looking at the rods, that they were not. Possibly the girder did not act as it was intended. But there was no trouble about the lower ones ; there was no swaying to them.

Mr. Osborn: I think that is what Mr. Lewis was endeavoring to explain. When the wheel was first started these rods were very slack, and that is why they put in the trussing. I went over the wheel in August, and even with the trussing five or six of them were loose as they came to the top, and then again tightened up. Whatever supposition was taken in calculating the wheel it seems to me that, theoretically, there must be a tendency to deflect the crown, and in going around at this point—what would correspond with the horizontal thrust—if there was no bracing, these rods would have to take it all. The question is, how much of that thrust is resisted by the rods, and how much would be taken up by the truss work. You might take out these rods entirely and you would still have a complete truss. It would require an application of the higher mathematics in order to determine the exact elongation and deformation. When you come to consider the thrust of the arch it is not readily determined whether the rods or the truss work take up that horizontal component. I would like to hear from some of the bridge men on that point.

The Chair: As Mr. Osborn says, it looks as if the complete determination of the stresses in every piece is a very complicated problem and one exceedingly difficult of solution. For this reason, I think it has not yet been completely solved, or at least only so far as to admit of the construction of one structure, which at present appears to be perfectly safe, and this, perhaps, is far enough for all practical purposes. Because a structure does not fail is no evidence at all that it has been constructed according to the best knowledge and engineering practice of the present day. It is exceedingly unfortunate that Mr. Searles has been unable to obtain the strain sheet, for then we should have some definite knowledge on the subject, whereas now, we are all more or less at sea as to the assumptions that were made in obtaining the strains in the different members. If the demand for this kind of structure increases we shall probably see very great changes from the present design, for it is highly improbable that the first design by two or three engineers should be the height of human perfection. Much credit is due to Mr. Gronau for the great care manifested in this work, and he must feel a just pride in thinking that this enormous piece of

machinery, the first ever attempted on so vast a scale, should be practically a success from the very first. To Mr. Ferris, great credit is due not only for the first thought of the wheel, but also for his successful management of the business part of the enterprise.

Mr. Searles: The diagonals in the rim remind me of the diagonals in the low trusses of the East River bridge, which are not designed to carry any load, as we ordinarily use that term, but merely to stiffen the floor locally. In the East River bridge the cables carry all the load, and the suspenders from the cable, while the low trusses with diagonals simply distribute the loads from the points where it is applied, in either direction indefinitely, and so serve to stiffen the floor against local deflection. I have the same idea about this truss. These diagonals in the rim are not to be construed as transmitting the load particularly anywhere, but simply to keep the outer chord in shape and let the outer chord do the work. That is the impression that has gained place in my mind.

Prof. Langley: That is just the opposite of Mr. Ferris' view.

Mr. Searles: The outer chord is very heavy, the web plate 24 inches wide and the top plate is 26 inches wide, while the inner ring or chord is composed of two ordinary channel bars with lacing to keep them in place. The section is lighter on the inner rim than the outer. Gronau must have considered the outer rim as the compressive member carrying the loads from the crown down to the lower part, and the posts and the diagonals acting no more than to locally stiffen the outer rim in order that it might do its work, and the radial rods, of course, connecting conjointly to keep the wheel in shape as a whole.

Mr. N. P. Bowler: I would like to know if there is anything about the construction of that wheel that would be injurious or detrimental, supposing it should be put upon the ground on the rim and made a big truck. Is the construction anything like our bicycles? Is the outer section or construction of it different from the tire or the felloe of the wheel? Not being used to figuring the sections of iron for bridge work, I am not familiar with the construction of that wheel.

The Chair: I will answer that question as far as my opinion goes, and that is, there is nothing in the design of the wheel to prevent it from rolling on the ground provided the rods are designed to carry it on the ground, and the rim is sufficiently strong to act as an arch: in other words it would roll like a bicycle wheel, so far as I can see, as long as the rods are sufficiently strong to carry the load.

About the bracing that Mr. Searles mentions, it is probably entirely for the side stiffness and not for the stiffness in other directions. Bracing in the plane of the wheel is not necessary. The outer rim would be sufficient to keep it in place, and it cannot be distorted as

long as the ring is stiff enough not to permit of bending. It is necessary to put these posts in on account of the large portion of the outer part of the wheel being without bracing. I think Mr. Searles is in error when he says one rim is not connected to the other. I think the pin to which the car is suspended goes completely through—or should—from one rim to the other and holds the two parallel, but it does not do any bracing.

Mr. Lewis: Those pins project inside of the outer rim probably 12 inches or such a matter. I tried to get that distance, but it is all covered by the top of the car. I should think these cars would weigh about twenty-six thousand pounds, and about five thousand pounds live weight inside would make thirty-one thousand.

Mr. Gifford: Begging your pardon, I can not agree with Mr. Porter in regard to that wheel rolling on the ground as in case of a bicycle wheel. That wheel is supported in its circumference at thirty-six points. If you rest it on the ground you must rest it at one point. Able as it is to be supported all around its circumference, I do not believe the thing would stand upright if it was left on edge to rest on the ground; it would "squash out" to use a common phrase, and the rods would break and the ring would flatten out. That is my idea of it.

The Chair: I do not say it would do so as at present designed. I said if the rods were designed to carry it on the ground, and the rim is sufficiently strong to act as an arch, it could be done.

Mr. Gifford: Then it would have to be built over again. I was trying to answer Mr. Bowler's question.

Mr. Bowler: That is the question I asked, whether it would stand as it is?

Mr. Searles: I think it is a very remarkable fact which should not be overlooked, that the projector of the wheel, Mr. Ferris, is a young man only twelve years out of school, and that Mr. Gronau, the perfector of the details, was only five years out of school. I think it is encouraging to the young men, and a good promise for America in the twentieth century.

Adjourned.

IRRIGATION—SOME NOTES ON THE ENGINEERING AND PRACTICAL FEATURES OF THE QUESTION.

By A. M. Van Auken, Member, Western Society of Engineers.

(Read November 1, 1893.)

In the paper to be read this evening no attempt will be made to introduce hydraulic formula or a mechanical discussion of the various structures which are needed, and altogether the paper will aim merely to give a general discription of the commoner methods of irrigation as practiced in the irrigation regions of Colorado and New Mexico.

The question of irrigation was forced upon the people of this region owing to the lack of sufficient rainfall during the growing seasons to sufficiently moisten the soil to bring any crop to maturity. The early irrigation ditches were built by the early, or Aztec, inhabitants which were quite crude. But very few traces of these, or what are known to be these, are now in existence in the country with which I am familiar.

There are throughout New Mexico, lands still inhabited by the semi-civilized tribes which it is very doubtful if the association with the Spanish invader has produced a beneficial effect. Upon these reservations or claims the irrigation is of the crudest sort. The ditches are small, have been mostly excavated by hand, have excessive fall and are subject to frequent washouts by floods.

The second stage of irrigation was introduced by the Mormon emigrants, many of whom came from Nauvoo in the State of Illinois, and by the colonists of Colorado who emigrated in the latter sixties and early seventies. Horace Greeley was looked upon as a patron saint of these latter and his name has been given to one of the most thriving cities which owes its existence to the success of irrigation. The irrigated farm and farmer have advantages not possessed by the farm and farmer whose dependence is upon natural rainfall. Natural rainfall is always uncertain and good crops are the rule in not over two years out of five. The other three crops are, to a great extent, failures, due, either to lack of rain or to too much rain. The farmer in the irrigation region has an abundance of sun-shine and the most delightful weather for the maturing and harvesting of all his crops, added to this, if he has a good ditch with good water rights lying above his lands, he is sure of a perfect crop each year if he uses intelligence in applying his water. His judgment in the proper time for, and the right amount used in the application of water, is where the educated farmer, or perhaps more truly said, the intelligent farmer possesses a very great ad-

vantage over his duller neighbor. Especially is this true in the case of fruits, large and small, and the growth of what are called root crops and potatoes.

Ex-Governer Eaton of Colorado, stated in the writer's hearing that the time of the application of water to a potato crop was a matter requiring the greatest judgment, that a man could add twenty per cent. to the yield per acre of his ground by making a difference of an hour in the time of applying his water. This perhaps, is a very strong statement, but the man making it has become wealthy from farming and his principal crops were potatoes and a rank growing variety of clover raised in the region called Alfalfa. As one can readily realize when you say that a man has a perfect crop every year, these farmers, on what are called poor years in the portion of the country depending on natural rainfall, reap a rich harvest. I will illustrate this by the case of H. M. Williams of Greeley, Colorado, who has a farm of eighty acres. This farm is in Alfalfa and potatoes in rotation. In the year of 1860 he raised 2,700 sacks of potatoes, which is equivalent to about 5000 bushels.

These were raised upon twenty-five acres of land. The crop sold that year for $3,600.00. The Alfalfa was not sold but was fed out on the farm to stock which he wintered for the owners. This crop averaged about four tons to the acre and it is worth at the farm, if any one wishes to sell it, about $4.00 per ton in the stack. In 1891 he had fifty acres in potatoes and sold a trifle over 5,000 sacks. This is just an average farm with an average water right on the vicinity. Mr. Williams spends the summer on his farm. The first of September, or thereabouts, his family move into the city of Greeley that his children may have the advantage of the city schools. He himself only visits his farm once or twice per week from the first of December until planting time in the spring, and it is only after school closes in June that his family returns to the farm. Mr. Williams informed the writer, three years ago, that while his book-keeping was not exact, that he was satisfied that his average income, above expenses, excluding his own time, had averaged above $1,800.00 per year for the previous five years, which time he had spent on his farm.

Having spoken of the benefits of irrigation, I wish to speak briefly of the problems. It is popularly believed in the irrigated country that the amount of water applied to the land from natural and artificial sources must be sufficient to cover the land 22 inches in depth in order to ensure a crop and as natural rainfall in that region is from nine to twelve inches as against 30 to 36 inches in Illinois, it will be seen that it is necessary to apply about 1 foot in depth of water to the land artificially. For this reason a common expression has arisen of an "acre foot" of water. In the early day the supply of water was abundant

and there was no difficulty if the ditch was led above a piece of land in having an abundant water supply, but that day has long since passed and to-day we find nearly all the principal rivers in Colorado with rights filed for two or three times the amount of water that ever finds its way into their channels. As soon as difficulties of this kind begin to arise, as the natural result the man nearest the head of the stream took all the water and the man farther down the stream was without any and his crops, after much work would, at a critical time, be left without water to shrivel, die and burn up before his eyes. This led to the enacting of laws to govern the appropriation of the water from the rivers and the doctrine of priority was cast in each law. Roughly speaking, priority means that the first man filing a claim on a stream is entitled to the amount of water he claims, provided he puts such water to useful purposes. The earliest method called for the appropriator driving a stake at the point along the river where he proposed to make his appropriation and attach to the stake a declaration of his intentions to make the appropriation of so many inches of water. An inch of water was the old mining term and means the amonnt of water which will flow through an orifice an inch square with the head variously stated in the laws of different States of four or five inches above the top of the opening. Within 30 days after the driving of this stake and the attachment of the paper the appropriator must have his declaration filed in the office of the register of Deeds of the County in which the ditch is located. He must also within 30 or 60 days, begin work on the ditch and push the work diligently and uninterruptedly until the ditch is completed. If the ditch is not completed within two years his filing lapses and becomes void. These laws have gradually been improved and added to until the office of State Engineer has been created in many of the States where irrigation is practised, and all declarations have to be filed in his office. When the water of a stream runs short a method has been devised of bringing the claimants into court and having the court pass on the validity of each water claim and adjudge to each its priority. This, in the case of the Platte River in Colorado, is a serious question. One of the oldest water claims being located below the mouth of the Cache le Poudre and in order that this ditch shall have its rights it is necessary to decide which, among the ditches on the water shed of the various streams flowing into the Platte, shall be cut short. As there are half a dozen or more such streams a great deal of work is necessary and gradually laws have been created dividing the State into "water districts," each of which water districts is aimed to cover a certain water shed, Each of these are under the direction of a Superintendent of irrigation. Each water district in turn is divided into various smaller districts, each of which is under charge of a water commissioner. It is now arranged so that

nearly all of these streams have a gauging station as far up into the mountain as it is feasible to locate it, which stations are equipped with automatic registering apparatus which registers the height of water in the river for each minute of the day and from each of these stations a daily report is sent to the State Engineer's office. These rivers having been gauged, and tables prepared showing the discharge of the stream for each foot and tenth of a foot in height of the river, the engineer knows at a glance what ditches are entitled to water and he can order the head gates raised or lowered as may be needed to give to each ditch the amounts to which it is entitled under its decree. An order is telephoned to the various water commissioners and if necessary, changes are made in the head gates of the canals to adjust them to the flow as it then exists. These head gates of the canal are set and locked by the water commissioners and it is a felony to in any way interfere with these head gates. This system results in a very fair distribution of the water among the priorities and it assures the water to those who are entitled to it. Division of the water after it gets into the canal is arranged by the management of the canal and is looked after by what are known as line riders. A man rides the length of the canal, or his section of the canal, each day and looks after its condition and sees that the lateral gates are not tampered with. These riders have a very busy time of it and the water commissioner's lot is seldom a bed of roses, there being an idea, which seems to be inherent in every American's mind, that air and water are the right of every man and if they can get the water by any means, fair or foul, they are justified in doing so.

Having given this brief description of the irrigation, we will proceed to what is the Engineer's part. The first question that is necessary for an engineer to settle is the quantity and regularity of his water supply. If the water naturally flowing in the bed of the stream is insufficient to supply prior appropriations and give him the amount of water needed for his canal, he must depend on catching the waste water of Spring floods and storing it until the time when it shall be needed. Owing to the great fall of land throughout Eastern Colorado and the rest of the irrigated region which varies from seven to forty feet to the mile, it is feasible to secure storage reservoirs without serious difficulty. These are generally made by selecting some depression which has an outlet through what is called in that country, a "draw" which would be called in New England, a "gulley." A dam, generally of earth, is thrown across this draw and raised to a sufficient height to store the amount of water wanted. The building of reservoirs and their location is quite a large subject and one of the branches of this is, in Colorado, what would lead to quite a violent dispute between advocates of what are called "mountain reservoirs" as against "plain reservoirs." The reser-

voirs on a plain can, as a rule, be more cheaply built than those in the mountains. They can also deliver their water to consumers with less waste from seepage. Their disadvantage is that the loss from evaporation is far greater than it is in the mountains and that, owing to their flat shape and comparatively shallow depth, the deposit of sediment is very much greater and much more difficult to get rid of. In the deep reservoirs on the canyons it is much easier to get rid of the silt by letting the water run off from the bottom in times of flood and carry away the heavier portions, which cannot be done in the shallow reservoirs. There is comparatively little engineering about the location of these reservoirs. The choice of location generally resolves itself in the choice between so small a number of available spots that by running a line of levels around for the water line and taking such measurements as are necessary to determine its capacity, a choice is easily made. When made, the dam which is to create the reservoir is the next matter for consideration. This is generally built of earth with the inner slope, or the slope next to the water of varying flatness, three to one being the least permissible slope. The outer slope is made about two to one and the top of the dam is made from three to six feet above the surface of high water in the reservoir and a spillway must be made, and the endeavor is to lead this away to some point as distant as possible from the dam and it must have, at some point of its course, bottom and sides of rock. This spillway must have a capacity to at least equal that of any expected inflow into the reservoir. The engineering connected with the location of the ditch is also an important matter. The early ditches were located by the use of what they call a level board which will be shown in the accompanying illustrations. A board about 16 feet long is taken and the two legs are given such a slant so as to make the length of the board from leg to leg 16½ feet. An ordinary plain level bulb is placed in the board, set in plaster of paris, care being taken to get it true as possible. If not exactly true when set, one of the legs is sawed off to make it true. With this board the miner or ranchman starts from his point of diversion sets the first leg at the elevation which he wants his ditch to have at that point. When I speak of the elevation of a ditch it refers to the elevation of the surface of the water in such ditch when it is running at its capacity. The second leg of the level board was moved till it reached a point where it was level at the surface of the ground. This operation is repeated, a stake being driven at each point, till the location of the ditch was finished. The fall was given to the ditch by placing a shingle or bit of other thin wood under the second leg, the thickness of which was equal to the fall which it was desired to give the ditch per rod in length. When this location was made taller stakes were driven at each point to mark the route and the land for several feet on the upper hill side of this

ditch is plowed, the plowman following the course from stake to stake. When the location of the ditch was thoroughly loosened by means of the plow an apparatus similiar to a snow plow used often on our city streets was used with two horses attached, to throw the earth out of the space plowed. This process was repeated a couple of times more and the ranchman had a ditch. In the second stage of ditch building, an engineer of more or less experience having some sort of a level and something he called a rod was called in and proceeded to make a similiar location to that made by the miner except that he used either a 33 or 66 foot chain and set his stakes that distance apart and adjusted his grade to that unit of length. The manner of excavation was the same as before except that as the depth of the ditch increased plows and scrapers were used. Later as water becomes more scarce more care is taken in building a ditch and it has been found advisable on the part of the ranchman to secure a first-class engineer with experience in ditch and canal building. The ordinary method pursued by an engineer in locating a ditch is to run one or two levelmen, according to the size of the work and the haste with which it must be done. The first line of levels is run as a contour line or rather as a line following the slope of the ground and having the fall which the engineer proposes to give his completed ditch. This line twists in and out and runs wheresoever it will. The party locating this is generally composed of four men. The levelman, level rodman, who also carries the front end of the chain, rear chainman and the man driving and carrying the stakes. The stakes used on this line are generally lath left full length and sharpened at one end. They are left long so that the line of the ditch is readily followed by the engineer in charge of the work.

The engineer follows up this work with range poles which he sets on the line where he wishes the ditch to run and the locating party follows with the permanent locating stakes. After the engineer has set the range poles the preliminary tall stakes are pulled up and taken to the wagon for further use. This locating party consists of levelman, rodman, who also serves as head chainman, rear chainman, stake marker and axeman. The stakes of this line are driven well down and numbered consecutively from the starting point, the same as in a railway survey. On this line levels are taken at all places where the ground changes and care is taken to get a correct profile. After the location is made a transit line is run close enough so that all points of the ditch line can be tied to it and this line is tied to all section corners and quarter corners that can be found, and the map is made which must be filed with the County Clerk in order to secure right of way for the ditch. Some of the later ditches which have been of larger size have been located with much more care and study. As much pains is taken with reconnaissance and the surveys as there ever was in the location of a railroad and all curves

of the canal are run in by transit and calculated with care. The cross section of the ditch is a matter requiring considerable care as it needs to be so proportioned as to secure the maximum of safety with the minimum of earth handled. It is desirous that the amount of earth excavated when placed in fills on one or both sides of the ditch shall just make a safe bank for the holding of water and guarding against floods. The structure in an irrigating canal or ditch are first the head gate and dam, or diversion vein, a sand gate, waste gates at points where danger from floods is to be feared, flumes over such streams as it is not feasible to cross by other means and the boxes or lateral gates. Dams and diversion wiers are avoided as far as it is possible to do so, by cutting the canal down to such a depth that the water from the river will flow in without artificial aid. A headgate is built at this point, to govern the amount of water admitted into the canal and generally a second gate is built far enough below to shut out all seep water from the canal. At this second head gate is placed a sand gate which is designed to keep most of the silt out of the canal.

It must be borne in mind that most of these mountain streams carry in suspension a large amount of earthy matter. As the velocity of flow in the irrigation ditch is much less than in the natural stream, it is desirable to exclude from the ditch all the heavier matters and admit only such as can be carried in suspension in the ditch. As a means of accomplishing this end, the sand gate is used. It is a gate with its top on a level with the sill of the head gate, and its bottom about one foot lower, and letting water into a ditch which permits it to flow back into the river at a high velocity. A head gate is nothing more nor less than a dam, having its piers connected with gates which can be raised or lowered as desired. Good dam construction makes good gate construction, and anything which would be condemned in the former would be unadvisable in the latter. Waste gates are usually provided by having a dam of wood substituted for the lower side of the canal at the threatened point, and making it much lower than the side of the ditch when made of earth. Several ingenious gates are made to act automatically. Two are patented, one by Gordon Land, of Denver, Colorado, and one by G. W. Barnhart, of California, and a non-patented one invented by A. D. Foote, of Idaho, which is shown in Fig. 2. Measuring boxes, placed at the head of all lateral ditches, are simply a box through the bank of the ditch to which is attached a gate so arranged that it can be locked at any height desired by the line rider and as is necessary to adjust the flow of water through it to the amount the consumer may be entitled. In the early days the ditch builders gave their ditches a grade of so much per rod, generally about one quarter of an inch per rod or nearly seven feet per mile. When ditches were first laid out by engineers a rule was adopted of a grade of five feet per

mile for a ten foot ditch and two and a half feet per mile for a twenty foot ditch. Ten and twenty feet referred to the width of the ditch at the surface of the water, and the grades were respectively one-tenth or one-half tenth of a foot per unit of one hundred feet. Experience has shown both of these grades to be too great, although some of the older engineers still cling to them. Some use even still greater, but now most engineers adopt a grade which will give a velocity of about three feet per second and determine this by using Kutter's Formulae, and using from .022 to .025 for co-efficient n.

To show how widely some depart from this I would mention the Del Norte Canal which is sixty feet wide and five and one-half feet deep, yet has a fall of about eight feet per mile. The High Line Canal near Denver has a fall one and three quarters feet per mile, is forty feet wide on the bottom and is seven feet in depth. Both of these are much too great and the additional cost of maintenance due to the excessive grade is very great.

Ditches are carried over streams in flumes which are usually framed bents, much like bridge bents with a wooden flume at the top with a proper grade and of suitable size to carry the water. In some of the canals attempts were made to carry the flumes across on fills of earth, but so much trouble was experienced from the leakage of the flume destroying the fill, that the plan was abandoned. In some of the later canals attempt has been made to use iron or steel trusses to carry the flume, but much trouble has been experienced arising from expansion of the metal. It has been found advisable not to use mortice and tenon in framing either bents or flume but to use bolts whenever possible.

Trusting that I have not over-wearied you with this paper's length, and thanking you for your attention, I will now close.

DISCUSSION.

Hiero B. Herr, Chairman:—I think we all ought to feel indebted to Mr. Van Auken for giving us a very interesting disquisition on a subject that I think most of us know very little about. I thought I did know something about it. I used to be in that country and saw some ditches, but it was before they got them up in the elaborate systems that they have now; it was before they had those districts that Mr. Van Auken speaks of. It is certainly a very interesting subject and it is now open for discussion.

Mr. Thos. Appleton:—I notice Mr. Van Auken speaks of Greeley, Colorado. It happens that I have visited that enterprising little city: at the time of my visit the water supply of the town was from these irrigation ditches. I understand since then they have put in a regular water pipe system. One of the features of that city that struck me as

new and novel was the height of the streets, the grade of the street in relation to that of the lot. A few years ago I was in East Saginaw, Michigan. There was a low, level, swampy region and it was necessary to drain the water down, to take the water out of the ground, to get rid of it in order to make it a habitable place, and in establishing grades in the streets care was taken to put the grade of the streets below the level of the adjoining lots so that the water from the lots might run off into the streets. When I reached Greeley, Colorado, I noticed the grades of the streets were in every place above the lots and along each street was an irrigation ditch. With the lots below the street the water would run from the street into the lot, just the reverse of the case I was familiar with in Saginaw. It was necessary that the streets should bring water to the lots; it was used on lawns and kitchen gardens, which were numerous and thrifty; in the other case we wanted to take the water away from the lots.

If I remember Mr. Van Auken's statement, he spoke of two ditches, one having a fall of eight feet to the mile, and the other a foot and three-quarters, and I understand that both were too much fall, is that correct?

Mr. Van Auken:—Yes.

Mr. Appleton:—Another matter, I understand that twelve inches of water per acre was considered necessary to operate and irrigate farms successfully. Well, if a farm gets less than twelve inches, can any kind of a crop be raised?

Mr. Van Auken:—Well, that depends on what you grow: some crops use more than others. Now, if a man has to take alfalfa, they get three crops, it has three irrigations; take wheat and barley, and you have got to have two or three irrigations for those. Potatoes only need one irrigation. If you have diverse kinds of farming, you can draw all your water for your potato crop just at the time you want it, and the other crop just the time you want it, and you do with a less amount of water. Now, this idea of a foot, that is, on the basis of a cubic foot per second, will irrigate about 100 acres of land, and under the "Farmers' High Line" ditch near Denver the amount of ground on which crops are raised is equivalent to about 190 acres for each cubic foot per second of water the ditch is able to secure. Our Major Powell has adopted the "Acre Foot" as a term describing water sufficient to cover an acre one foot deep, as being the amount of water necessary.

Mr. Appleton:—The water is supplied only a short time during the season,—it does not have to run all the year, only a short time?

Mr. Van Auken:—Only a short time.

Mr. Appleton:—Is that during the season of rainfall?

Mr. Van Auken:—The rainfall is not very much of an item. The

record of the city of Denver since there has been a signal service station there, is that they have averaged, I think, seven days in a year when the sun was totally obscured, so that it is a region of sunshine, and the natural rainfall does not cut very much of a figure. It is at Denver from nine to twelve inches per year, that includes the snow of the winter and all. The mountains give a great deal more rainfall. The Signal Service Station on Pike's Peak showed a rainfall three times as great as it did in Denver the same year.

Mr. Karner:—During the time of rainfall irrigation would not be needed.

Mr. Van Auken:—The irrigation is necessary to a certain period of the growth of each crop and with potatoes they fairly drench the ground so that when you walk over it your foot will sink in very nearly as deep as the ground is plowed, just about as deep as in a dusty street after a heavy rain: you will go through that dust just as in a potato field you go through the soft ground. That is just when the potatoes are set.

Mr. Karner:—There is moisture enough in the earth for the crop when you get it started.

Mr. Van Auken:—Yes.

Mr. Karner:—Do you know what the cost of that land would be to that eighty acre farmer per year?

Mr. Van Auken:—Well, I can hardly say as to the cost of applying water. I think he employs two men on his farm—two men during the growing season and one man the year round. Then the cost of the water from the ditch amounts to about—I have to use their terms, their inch of water—about 25 cents per inch is what his assessment is per year in the ditch and he has about forty acres. I think his water right is about forty or fifty inches.

Mr. Karner:—I understand those ditches are under the control of the State.

Mr. Van Auken:—The distribution of the water is under the control of the State; the ditches are owned by either private companies or corporations, the better ones, the more successful ones are co-operative. Some of the larger ones are owned by stock companies; people either buy the water as you buy it from the water company in the city, or buy a water right entitling them to so much water with a certain annual charge. The co-operative ditches are like any stock company, the stockholders are entitled to the assets of the company, and the assets of the company in this case are water. Each share of stock is entitled to its share pro rata of the water. A good ditch having good water right increases in value very rapidly, and a company selling water rights is looked upon by the farmers as a monopoly, and the bitterness that they feel in the East towards monopolists in factories

and railroads is only a fraction of the bitterness they feel towards ditch corporations, except when they are the stockholders and own the water. If it increases in value it is theirs and it is all right.

Mr. Weston:—I should like to know how the water is distributed. I have seen the distribution of water from wells in the southern part of Europe, in the orange gardens, etc. How is the water distributed over the land from these ditches?

Mr. Van Auken:—(Illustrating on blackboard). Suppose your ditch flows in this direction. The way they get the water on the land, they will put a dam in the ditch, right there (indicating). He is starting in to irrigate to here, the fall of the land is supposed to be in this direction, and he puts some dam in the ditch at that point, takes a few shovels full of earth out of the ditch here and lets it run, then he follows around with a long-handled shovel, and that is the tool that the irrigator is proud of, his shovel: they have got to be the best of steel, and they are polished as nice as any house-wife keeps her silver, you can see them shining in the sun a long way off.

The Chair:—That is not in the main ditches?

Mr. Van Auken:—No, that is in the lateral ditch, and he guides the little stream and runs it there—all the volume that he can—until that soil is thoroughly drenched so that his feet can go clear down deep in it. They have a very reckless way of working in the wheat field. They will go in and take a shovelfull of wheat here and there and throw it down somewhere else, as though it did not amount to much. When he has irrigated all he can there to advantage, he removes this and takes it further down, and continues on until he has gone over his entire field.

Mr. Weston:—It must take some days?

Mr. Van Auken:—Yes, a man can irrigate about four or five acres a day if it is well located.

Mr. Ewing:—What is the general character of the earth, the soil, that these ditches are run through?

Mr. Van Auken:—Well, it looks very much like the sand not immediately on the beach, but a little further back, where there begins to be some vegetation along one of the lakes, that is the impression it gives one.

Mr. Ewing:—The impression I had was there would be considerable seepage from the drain, and the question arises whether it would not be feasible, and a good investment, to puddle the main ditch.

Mr. Van Auken:—That is done naturally. All these mountain streams carry a great deal of sediment and this very quickly coats the inside of the ditch. After water has run into a ditch for a short time the inside of it will be just like putty, and unless the ditch be through a shale rock or coarse gravel it will make it practically tight.

Mr. Ewing:—Do you tramp them down?

Mr. Van Auken:—Just as the horses used on the scrapers during construction tramp it in going back and forth.

Mr. Ewing:—You do not exercise any extraordinary care with it?

Mr. Van Auken:—No.

Mr Ewing:—I understand in California a gentleman has been investigating the question as to when irrigation should be applied, and he considers that he can judge by the action of the leaves. If a man becomes rather expert he can tell by the looks of the leaves just about when to water. Then he lets it go again until the leaves again show that water is needed.

A Member:—In California the water has become more valuable than at other points.

Mr. Van Auken:—The crops there are more largely fruit and will warrant a person incurring more expense. In Colorado the crops are potatoes, alfalfa and some grains, the nights are too cold to permit them to grow corn.

Mr. Barlow:—Speaking about seepage, I had occasion to know what seepage is in the State of Washington. It has the same sandy soil that you speak of in Colorado. It is the soil that gives one the impression that it might take ten years before you would get to the end of the ditch, and the water was turned in there, some days it would go six or eight miles in a day, and some days it would not advance—the first water that went into the ditch, some days it would not advance more than a mile, some days it would seem almost stationary, and altogether it would take ten days to get to the end, and after it had been running about three weeks it was measured at the head and measured at the lower end without any being turned in in the laterals and they counted seventy-six per cent. of the water at the lower end, that was expended at the head, and they thought that was a very good result. I do not know what the average result is in ditches after it has been running several years. I should like to ask about what price per acre it costs in the main canals in Colorado—what the construction price of getting water on the land is.

Mr. Van Auken:—That is a very difficult question to answer. The companies that sell water rights, that build the main canal, charge for a water right $8.00 per acre along the first forty miles of the ditch, $10.00 an acre below that, that is supposed to cover the cost of building a canal, $8.00 to $10.00 an acre.

Mr. Barlow:—There is some very valuable land in southern Idaho for irrigation and they have gone into it quite largely there and their estimated costs varies from $3.50 to$6.00 an acre, but I do not know of any other portion of the country that offers as favorable fields for construction in the way of ditch construction per acre as it does there.

In the State of Washington it runs up to $12.00 and $14.00 an acre. The entire ditch out there, sixty miles along the grant is worthless without water, and the company have acquired land from the railroad company land grant and control a large amount of those lands and they have built the ditch, about sixty miles in length and they now throw that land open to purchasers at the rate of $50.00 per acre, that is where the money comes in.

A MEMBER:—Does that include the permanent water right?

MR. BARLOW:—That includes the permanent water right with the exception of assessment for maintenance which amounts to $1.00 or $1.25 per acre.

MR. EWING:—I understand that some portions, at least in the vicinity of Fresno, California, the work is done very cheaply, that is the grading, I believe is done in some places as low as 5 cents a yard.

MR. VAN AUKEN:—I could not say as to that, but through eastern Colorado and western Nebraska I know contracts to be made as low as 6 cents a yard.

MR. BARLOW:—In the State of Washington that actually costs the contractor less than 4 cents a yard, using the new kind of grader, and the contract price was in some instances 7 cents, and they are unusually cheap and unusually good grounds for handling those machines.

THE CHAIR:—In regard to the cost per acre of this work I should think that would vary with almost every different ditch. We know some of those ditches, I have seen in Colorado for instance, there are miles of ditch before you come to any land to irrigate. They may be very wide, the tract which is to be irrigated, or may be narrow, so that the cost per acre would depend on the number of acres that a certain ditch would take care of, I should think for its size. That would vary so so much in different localities, so that it would only be by knowing the cost of a number of different cases, that an engineer would be able to get at a probable cost without actually making the surveys determining the water.

A MEMBER:—In some places you have only to go a short distance, others if the country is naturally flat you have to start a long way up the stream. I made a survey three years ago for a canal that was 140 miles before it reached the territory that it was primarily to cover, it never reached the territory because the cost was too great.

MR. VAN AUKEN:—If you are on a side-hill it is cheaper to make your ditch deep, if you are on a fairly level land, it is cheaper to make it wide and shallow, because of the economy of excavating; with the side-hill it is cheaper to make it narrow. You have got to know the locality before you can determine the best and most economical shape for your ditch.

THE CHAIR:—In regard to the legal aspect of these rights,—after a

certain right is obtained for so much water leading out from a stream, others may ask for further rights, and means for more water will be taken through this first ditch—the ditch must be increased in capacity for their additional right. I was curious to know how that increase is made, who does that, how they get at that to enlarge a ditch?

MR. VAN AUKEN:—Most ditches are made a great deal larger in the beginning than the probable demand. And then again, the same question that was brought out—a new ditch loses a great deal from seepage and that loss continually grows less and it can supply a few more consumers each year. But now, for instance take this Oligarchy ditch, when it was begun there were four farmers that owned land for four miles along the stream, they built the ditch for their own supply. Some other people got land further down the stream and they made surveys and they found they could get water through the Oligarchy to their land and the law provides that you cannot cross a man's land with a second ditch provided you can get water through the first. It also provides that you can condemn the right to carry water through this first ditch, and having those rights, it is generally easy to obtain concessions, and this has gone on, the length being increased, until there are five different rights to the Oligarchy.

THE CHAIR:—The provision then in the law for condemnation is really the way that is accomplished?

MR. VAN AUKEN:—Yes.

THE CHAIR:—When necessary they can increase the size?

MR. VAN AUKEN:—Yes. Under the law you can require them to carry it for you if their capacity will allow. If their capacity is not sufficient, they must allow you to enlarge it.

MR. EWING:—Who decides that question, the State Engineer?

MR. VAN AUKEN:—Well these laws are a gradual growth, originally they had nobody, but the engineer measures the stream and when a stream has been appropriated he will not allow any further appropriations,—in Colorado there is no law, you can appropriate forever. But beginning in Colorado, it grew out of the miners' ditch. The miner built a ditch for hydraulic mines and they used the permit and changed it into water rights, this is something they understood and the law gradually grew from that, and they have continued the laws but they are still very crude in Colorado. In the point raised by Mr. Ewing, if it cannot be arranged amicably it must go into the courts.

MR. EWING:—Another part of the subject rather interesting is to show the use of water in irrigation and hydraulic mining. You will all remember there was a great strike in California regarding whether gold or agriculture interests were to predominate in the valleys; they have had to give it up and I understand in the valleys where Placer mining was further prohibited on account of washing this dirt on the

farm lands, that they have raised almost ten-fold the amount in agricultural products that were mined out of the hills which they washed with the Placer mining.

Mr. Van Auken:—There is one point while speaking of the law,—you may have heard of the Wright Law in California. That law provides, roughly speaking, for the formation of an irrigation district and that district can vote bonds just the same as you can vote bonds to build a school-house or city-hall, they vote bonds for building and buying a ditch, and you can tax all the property that will be benefited by that ditch, and it is a law that has worked very finely there. It has enabled them to get rid of ditches that were owned by non-residents and run them in the interest of the community, and it has enabled them to tax lands that benefited by the rise of value, but whose owners would not contribute towards building these ditches. That is probably the latest in irrigation laws.

Mr. Barlow:—That is precisely the case in one of these ditches in the irrigation district of getting together and voting to buy out this thing. They saw the monopolistic elements staring them in the face, and before they actually began using the water, formed themselves into an irrigation district, bonded themselves sufficiently to take up all the outstanding obligations to the Company, to invest themselves with the monopoly rather than non-residents.

The Chair:—They objected to the monopoly when they were not in it. I am sorry there were not more members here to hear this paper and the talk on it, because this question is becoming a wonderfully interesting subject. There are some very large organizations—not in the region Mr. Van Auken speaks of, that is, further down the mountains, down in Kansas and Nebraska—there are some large corporations operating there and it is going to be an immense factor in the agricultural products of this country in ten or twenty years and must necessarily, therefore, be interesting not only to engineers but as a material industry of the country.

Mr. Karner:—They are adopting it largely in New Mexico, I believe.

The Chair:—I would like to ask Mr. Van Auken whether he found in the Moquegua region in New Mexico,—I noticed a very old ditch there and a very long one which can be seen in places, deteriorated now, but I have had no time to go into it—I thought possibly you might know of it.

Mr. Van Auken:—I do not. I know there was such a ditch, but I never saw it.

The Chair:—I was very much surprised to find that the primitive people had built such extensive ditches, twenty-five to thirty miles long. I thought possibly you might know definitely about it.

THE HINGED SUSPENSION BRIDGE.*

By Prof. Malverd A. Howe, Member Engineers' Club of St. Louis.

[Read June 14, 1893.]

The form of suspension bridge, considered in the following pages, consists of supporting cables carrying by means of vertical (in projection) suspenders, stiffening trusses which are hinged at the ends and in the center of the span. Longitudinal movement of the trusses can be provided for either at the end pins or at the center pin.

In deducing the formulas for shears and moments, it will be assumed that the stress in the suspenders is uniform per lineal foot of the span for any combination of loads; that is, the trusses are supposed to have sufficient stiffness to distribute any load so that the cables will be uniformly loaded from end to end; secondary cables will be omitted and the main cables assumed fixed at towers having equal elevations.

NOMENCLATURE.

L = one half the distance between the end pins.

P_1 = any concentrated load in the *first arm.*

P_2 = any concentrated load in the *second arm.*

w = any uniform load per foot run.

p = the length of the panel in the stiffening truss.

V = the stress in any vertical suspender.

$v = V \div p$.

a_1 = the abscissa of the point of application of P_1 or $a_1 = k_1 L$.

a_2 = the abscissa of the point of application of P_2 or $a_2 = k_2 L$.

a_1 and a_2 always being measured from the pin immediately on the left.

S_1 = the shear just on the *right* of A.

S_2^1 = the shear just on the *left* of Z.

S_2 = the shear just on the *right* of Z.

S_3^1 = the shear just on the *left* of A^1.

S_x = the shear at any point in the *first arm.*

M_x = the moment of any point in the *first arm.*

x = the abscissa of any point in the *first arm*, or $x = z L$.

END SHEARS AND STRESSES IN THE SUSPENDERS.

Loads in the first arm. From Fig. 1, since the sum of the vertical

* See *Annales des Ponts et Chaussées*. November, 1892. Paper by Louis de Boulongne.

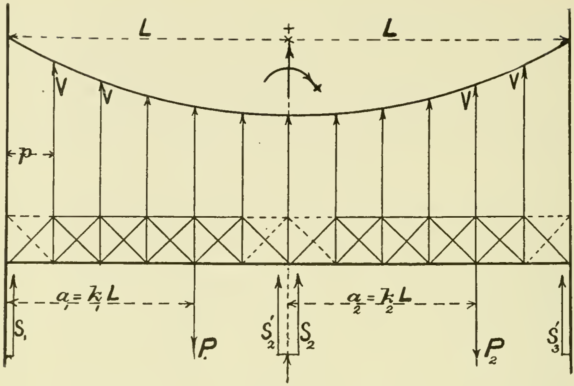


FIG. 1.

forces and the sum of the moments at any point must be zero, we have:

$$S_1 + v\,L + S_2^1 = P_1$$
$$-\,S_2^1 + v\,L + S_3^1 = O$$
$$\frac{v\,L^2}{2} + S_2^1\,L = P_1\,a_1$$
$$\frac{v\,L^2}{2} - S_2^1\,L = O$$

from which we readily obtain

$$S_2^1 = \frac{1}{2}\,P_1\,k_1$$
$$S_1 = \frac{1}{2}\,P_1\,(2 - 3\,k_1)$$
$$v = \frac{k_1}{L}\,P_1$$
$$\mathrm{V} = \frac{p}{L}\,P_1\,k_1$$

Loads in the second arm. For loads in the second arm, we have only to replace k_1 in the above equations by $1 - k_2$, and P_1 by P_2 and obtain:

$$S_2^1 = \frac{1}{2}\,P_2\,(1 - k_2)$$
$$S_1 = -\,\frac{1}{2}\,P_2\,(1 - k_2)$$
$$v = \frac{1}{L}\,P_2\,(1 - k_2)$$

$$V = \frac{p}{L} P_2 (1 - k_2)$$

Combining the equations for loads in the first arm with those for loads in the second, and writing ΣP_1 and ΣP_2 for P_1 and P_2 respectively, we obtain the following general equations:

$$S_1 = \frac{1}{2} \Sigma P_1 (2 - 3 k_1) - \frac{1}{2} \Sigma P_2 (1 - k_2) \qquad (a)$$

$$S_2^1 = \frac{1}{2} \Sigma P_1 k_1 + \frac{1}{2} \Sigma P_2 (1 - k_2) \qquad (b)$$

$$V = v p = \frac{p}{L} \Sigma P_1 k_1 + \frac{p}{L} P_2 (1 - k_2) \qquad (d)$$

where Σ is the sign of summation.

BENDING MOMENTS.

Loads in the first arm. (a) Bending moments due to loads on the right of the center of moments.

$$M_x = S_1 x + \frac{v x^2}{2}$$

or

$$M_x = \frac{L}{2} P_1 z (2 - 3 k_1 + k_1 z)$$

(b) Moments due to loads on the *left* of the center of moments.

$$M_x = S_1 x + \frac{v x^2}{L} - P_1 (x - a_1)$$

or

$$M_x = \frac{1}{2} L P_1 k_1 (2 - 3 z + z^2)$$

Loads in the second arm. (a) Moments in the first arm due to loads in the second arm.

$$M_x = S_1 x + \frac{v x^2}{2}$$

or

$$M_x = \frac{1}{2} L P_2 z (k_2 - 1) (1 - z)$$

Combining the above equations and writing Σ before P_1 and P_2, we have the following general equation of moments in the first arm.

$$\begin{aligned} M_x = {} & \frac{1}{2} \Big(\Sigma P_1 k_1 (2 - 3 z + z^2) \Big) \\ & + \frac{L}{2} \Big(\Sigma P_1 z (2 - 3 k_1 + k_1 z) \Big) \\ & + \frac{L}{2} \Big(\Sigma P_2 z (k_2 - 1) (1 - z) \Big) \end{aligned} \qquad (e)$$

We have now deduced the general equations for end shears and moments at any point for the stiffening trusses: in investigating the intermediate shears, their maximum values and the maximum moments, we will resort to graphical methods as being clearer and shorter for practical use.

GRAPHICAL DETERMINATION OF S_1.

Diagram I. Make $A\ Z = Z\ A^1$ and lay off the values of k_1 and k_2 as shown. Make $A\ c = 1$, $Z\ a = \frac{1}{2}$ and draw the right lines $c\ b\ a$ and aA^1. Then the value of S_1 for any load P_1 where $k_1 = 0.4$ for example, is equal to the ordinate at P_1 multiplied by P_1 or in this case $S_1 = 0.4\ P_1$.

S_1 is positive for all loads on the left of b where $k_1 = \frac{2}{3}$ and negative for all loads on the right of b.

Proof:

From the triangle $A\ b\ c$

$$A\ c : m\ (0.4) :: A\ b : (0.4)\ b \quad \text{or in general}$$

$$1 : S_1 \div P_1 :: \tfrac{2}{3} : \tfrac{2}{3} - k_1$$

and $$S_1 = \frac{1}{2}\ P_1\ (2 - 3\ k_1)$$

From the triangle $b\ Z\ a$

$$-\frac{1}{2} : S_1 \div P_1 :: \frac{1}{3} : k_1 - \frac{2}{3}$$

and $$S_1 = \frac{1}{2}\ P_1\ (2 - 3\ k_1)$$

From the triangle $a\ Z\ A^1$

$$-\frac{1}{2} : S_1 \div P_2 :: 1 : 1 - k_2$$

and $$S_1 = -\frac{1}{2}\ P_2\ (1 - k_2)$$

GRAPHICAL DETERMINATION OF S_x.

Diagram I. Make $A\ c = 1$, $t\ d = \frac{1}{2}$ and $t\ e = \frac{1}{2}$ using the scales employed above, and construct the parabola $c\ l\ d\ e$.

For example, suppose the values of S_x are desired for the load P_1 when $k_1 = 0.4$. Through f where the ordinate $o\ f$ (0.4) cuts the parabola draw the right line $h\ f\ e\ l^1$. Then for shears on the left of the load take the ordinates at the *centers of the panels* between the lines $h\ f$ and $A\ Z$ and multiply them by P_1, the results will be the values of S_x. *Use scale $c\ h\ A$.*

For shears on the right of the load proceed in a similar manner but read the ordinates between $f\ e\ l^1$ and $o\ e$. *Use scale $t\ s\ d$.*

In case the line h f e crosses A Z the ordinates read above A Z will be negative as shown on the diagram.

Thus it appears that by drawing a right line for each load in the

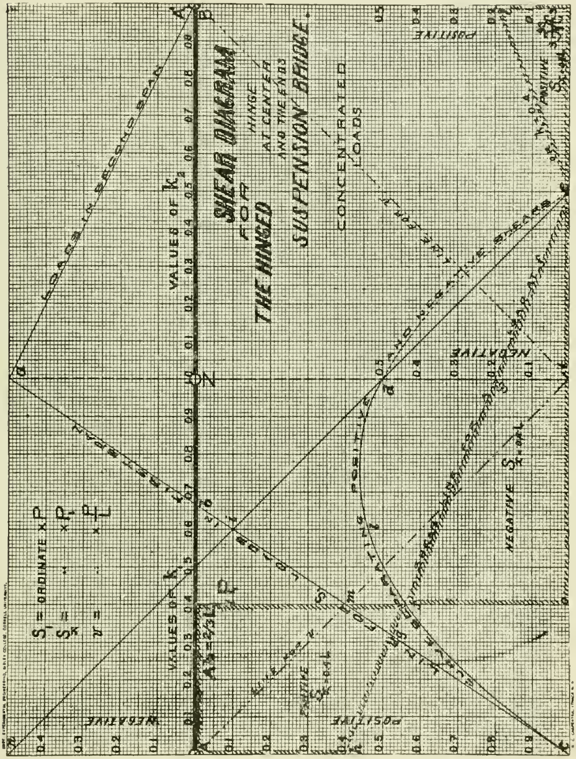


DIAGRAM I.

first arm that the values of S_x can be tabulated and the maximum intermediate shears readily found.

According to our assumption, the cable is always uniformly loaded, then for a load at each panel point in the first and second arms the trusses would not be subjected to any shear, hence the maximum pos-

itive and negative shears must be equal: hence it is necessary to determine the positive shears only.

Proof.

For shears on the right of the load we have

$$S_x = \frac{1}{2} P_1 (2 - 3 k_1) + \frac{1}{L} P_1 k_1 x - P_1$$

by substituting the values of S_1 and v in the equation

$$S_x = S_1 - v x - P_1$$

For the shear when $x = k_1$ or immediately at the load we have

$$- S_x = P_1 \left(\frac{3}{2} k_1 - k_1^2 \right)$$

By construction $c f d e$ is a parabola of which we know the chord $c e = \frac{3}{2}$ and the ordinate $d t = \frac{1}{2}$.

Any ordinate as $o f$ can be found from the equation

$$o f = (c e - c o) c o$$

or $o f = \frac{3}{2} k_1 - k_1^2$

or the ordinates of the parabola equal $- S_x \div P_1$ immediately at the point of application of the load, that is, if the panels are supposed to be indefinitely short.

Returning to our general equation we have by reduction

$$- S_x = P_1 \left(\frac{3}{2} k_1 - z k_1 \right) \text{ where } z = \frac{x}{L}.$$

This is an equation of a right line

$$\text{For } z = k_1, \ - S_x = P_1 \left(\frac{3}{2} k_1 - k_1^2 \right), \quad \text{for } z = \frac{3}{2},$$

$$- S_x = 0, \quad \text{for } z = 2, \quad - S_x = - \frac{1}{2} k_1 P_1$$

These conditions are fulfilled by the right line $f e l$.

For shears on the left of the load

$$S_x = \frac{1}{2} P_1 (2 - 3 k_1) + P_1 k_1 z$$

which is an equation of a right line.

For $z = 0$, $S_x = S_1$ and for $z = k_1$

$$S_x = P_1 - \left(\frac{3}{2} k_1 - k_1^2 \right) P_1$$

These conditions are fulfilled by the right line $h f$.

GRAPHICAL DETERMINATION OF MOMENTS.

Diagram II. Let $A\ Z\ A^1$ represent the entire span and mark the divisions corresponding to the panel points by the proper values of k_1 and k_2.

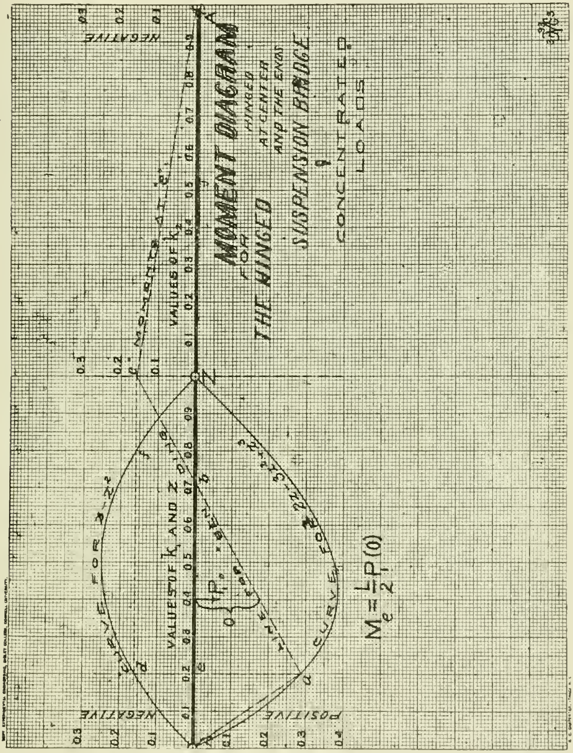


DIAGRAM II.

Construct the two curves $A\ a\ Z$ and $A\ d\ Z$ having ordinates $2z - 3z^2 + z^3$ and $z - z^3$ respectively.

Suppose the bending moment is desired at e. Draw $A\ a$, $a\ b\ c$, and $c\ A^1$, then the moment at e due to the load P_1 where $k_1 = 0.4$

equals $M_e = \frac{L}{2} P_1$ (ordinate between A Z and a b at 0.4). Proceed in like manner for any load.

Proof.

For loads on the left of e

$$M_e = \frac{L}{2} P_1 k_1 (2 - 3z + z^2)$$

For $k_1 = 0$, $M_e = 0$ and for $k_1 = z$

$$M_e = \frac{L}{2} P_1 (2z - 3z^2 + z^3) = \frac{L}{2} P_1 (a\ e)$$

For loads on the right of e

$$M_e = \frac{L}{2} P_1 z (2 - 3k_1 + k_1 z)$$

For $k_1 = z$, $M_e = \frac{L}{2} P_1 (2z - 3z^2 + z^3) = \frac{L}{2} P_1 (a\ e)$

For $k_1 = \frac{2}{3 - z}$, $M_e = 0$

For $k_1 = 1$, $M_e = -\frac{L}{2} P_1 (z - z^2) = -\frac{L}{2} P_1 (c\ Z)$

For loads in the second arm

$$M_e = \frac{L}{2} P_2 z (k_2 - 1)(1 - z)$$

For $k_2 = 0$, $M_e = -\frac{L}{2} P_2 (z - z^2) = -\frac{L}{2} P_2 (c\ Z)$

For $k_2 = 1$, $M_e = 0$.

All of the above conditions are fulfilled by the lines $A\ a\ b\ c\ A^1$.

Thus it appears that by the aid of Diagrams I and II, all shears and moments can be determined for each load, a table formed and the maximum values determined. Since the maximum positive and negative shears and moments are equal respectively, the final results are checked, the positive being equal to the negative.

UNIFORM LOADS.

In case the panels are very short or great in number, we can, without serious error, assume the loading to be uniformly distributed, and if desired, in case of railway bridges, an excess in the form of a concentration added.

The stresses due to the excess can be found by means of the Diagrams explained above; for the uniform load we have deduced formulas for the intermediate shears and the moments, and also constructed a Diagram from which their maximum values at any point can be quickly determined.

By making $\Sigma\ P = \int w\ d\ a$ in all our formulas for concentrated loads reducing etc., we obtain

For intermediate shears in the first arm

$$S_x = \pm\ \frac{w\ L}{4}\ \frac{(2 - 3\,z + 2\,z^2)^2}{3 - 2\,z}\ \text{for}\ z \leqq \frac{1}{2} \qquad (20)$$

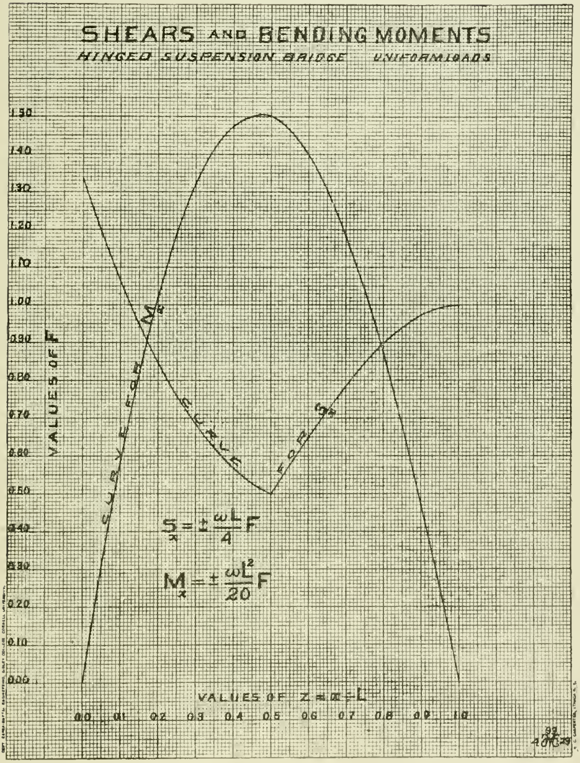


DIAGRAM III.

$$S_x = \pm\ \frac{w\ L}{4}\ (2\,z - 3)\ z^2\ \ \text{for}\ z \geqq \frac{1}{2} \qquad (21)$$
$$z \leqq 1$$

The values of $\frac{(2 - 3z + 2z^2)^2}{3 - 2z}$ and $(2z - 3)z^2$ are given on Diagram III and in Tables II and III.

For bending moments

$$M_x = \pm \frac{w\ L^2}{2} \left(\frac{2z - 3z^2 + z^3}{3 - z}\right) \qquad (22)$$

where z has values from 0 to 1.

The values of $\frac{2z - 3z^2 + z^3}{3 - z}$ are given on Diagram III and in Table I.

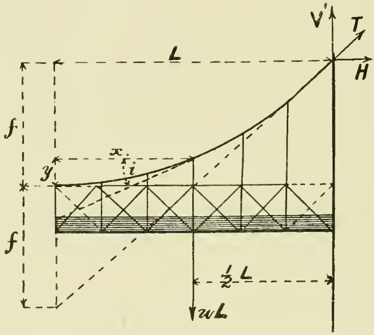


FIG. 2.

STRESS IN THE CABLES.

$$H = \frac{v\ L^2}{2\ f} \qquad (25)$$

$$V^1 = v\ L \qquad (26)$$

$$T = \frac{v\ L}{2f} \sqrt{4f^2 + L^2} \qquad (27)$$

DEFLECTION OF THE CABLES.*

$$\triangle\ s = \frac{4}{3}\frac{f}{L} \triangle\ f \text{ and } \triangle\ f = \frac{3}{4}\frac{L}{f} \triangle\ s \qquad (28)$$

where $\triangle\ s$ is the change in the length of the cables, and $\triangle\ f$ the corresponding change in f. Fig. 2.

* *Enc. Britt.* Vol. IV. Bridges.

TEMPERATURE STRESSES.

In case the towers are composed of the same material as the trusses and cables the change in temperature will not affect the stresses. If the towers are composed of masonry the temperature will affect the stresses in the center and end suspenders. For spans up to 1,500 feet the end suspenders may be doubled in cross-section, and those at the center hinge be given a section from 1.4 to 5.0 times the section of the other suspenders for spans from 150 to 1,500 feet respectively.

A discussion of this question can be found in *Annales des Ponts et Chaussees*, November, 1892, in a paper by Louis de Boulongne.

TABLE I.

Values of $u = \dfrac{2z - 3z^2 + z^3}{3 - z}$

z	u
0.00	0.0000
0.05	0.0314
0.10	0.0589
0.15	0.0827
0.20	0.1029
0.25	0.1193
0.30	0.1322
0.35	0.1416
0.40	0.1477
0.45	0.1505
0.468	0.1506*
0.50	0.1500
0.55	0.1464
0.60	0.1400
0.65	0.1306
0.70	0.1187
0.75	0.1041
0.80	0.0873
0.85	0.0682
0.90	0.0471
0.95	0.0243
1.00	0.0000

* Maximum value of u.

TABLE II.

Values of $u' = (2z - 3)z^2$

z	u'	z	u'
0.50	0.500	0.76	0.855
0.51	0.515	0.77	0.866
0.52	0.530	0.78	0.876
0.53	0.545	0.79	0.886
0.54	0.560	0.80	0.896
0.55	0.575	0.81	0.905
0.56	0.590	0.82	0.914
0.57	0.604	0.83	0.923
0.58	0.619	0.84	0.931
0.59	0.634	0.85	0.939
0.60	0.648	0.86	0.947
0.61	0.662	0.87	0.954
0.62	0.667	0.88	0.960
0.63	0.691	0.89	0.966
0.64	0.705	0.90	0.972
0.65	0.718	0.91	0.977
0.66	0.732	0.92	0.982
0.67	0.745	0.93	0.986
0.68	0.758	0.94	0.990
0.69	0.771	0.95	0.993
0.70	0.784	0.96	0.995
0.71	0.796	0.97	0.997
0.72	0.809	0.98	0.999
0.73	0.821	0.99	0.9997
0.74	0.832	1.00	1.000
0.75	0.844		

TABLE III.

$$\text{Values of } u'' = \frac{(2 - 3z + 2z^2)^2}{3 - 2z}$$

z	u''	z	u''
0.00	1.333	0.26	0.740
0.10	1.303	0.27	0.725
0.20	1.273	0.28	0.710
0.30	1.243	0.29	0.696
0.40	1.215	0.30	0.682
0.50	1.187	0.31	0.669
0.60	1.159	0.32	0.666
0.70	1.133	0.33	0.644
0.80	1.107	0.34	0.632
0.90	1.081	0.35	0.620
0.10	1.057	0.36	0.610
0.11	1.032	0.37	0.599
0.12	1.009	0.38	0.589
0.13	0.986	0.39	0.579
0.14	0.966	0.40	0.570
0.15	0.942	0.41	0.561
0.16	0.921	0.42	0.552
0.17	0.901	0.43	0.544
0.18	0.881	0.44	0.537
0.19	0.861	0.45	0.530
0.20	0.843	0.46	0.523
0.21	0.824	0.47	0.516
0.22	0.806	0.48	0.510
0.23	0.789	0.49	0.505
0.24	0.772	0.50	0.500
0.25	0.756		

ERRATA.

In November issue, in 2nd. line from bottom of page 509, read *Cordouan* for "Cordovan," and *Gironde* for "Geronde." In 13th. line, page 519, read *Lubec Channel* for "Lubee Channel." In 9th. line, page 521, read *of* for "at."

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

ENGINEERS' CLUB OF ST. LOUIS.

388TH MEETING, NOVEMBER 15TH, 1893. The Club met at 8 p. m., November 15, 1893, at Washington University, with President Moore in the chair and 25 members present.

Prof. Wheeler was appointed Secretary pro tem. in the absence of Mr. Thacher.

The minutes of the 387th meeting were approved.

The action of the Executive Committee at their 150th meeting was reported.

Messrs. Arthur L. Tuttle, E. M., and Richard McCulloch, E. M., were elected to membership.

Ten members were nominated for a committee on nominations, from whom the following five were elected: W. H. Bryan, Carl Gayler, Wm. Bouton, Julius Baier, B. H. Colby.

The paper of the evening, by Prof. W. B. Potter, on "Progress of Smoke Abatement in St. Louis," was then read. Prof. Potter stated that two inspectors had been appointed, who had been busy on preliminary work for the past two months, and that prosecutions were now about to be started against offenders, for which purpose a special attorney had been secured by the Citizens' Executive Committee; that a month's notice was served on offenders after having been reported by the inspectors, after which time they would be prosecuted if they did not abate their smoke; that the Smoke Prevention Committee, of which Prof. Potter was chairman, were not prepared to make a final report, as only three devices had been thoroughly tested—the Hawley down-draft, the Boileau and the zig-zag grate bar; that about fifty different devices for preventing smoke were in use in St. Louis, some of which were quite extensively and successfully used; that difficulty was found in getting accommodations for testing new devices, but that five more were to be tested next month: that the steam jet principle was used in many of the devices, the down-draught in several others, and coking arches in others: that so-called combustion powders or compounds, to add to coal before or during use, were being advocated, which usually consisted of about twenty-five per cent. of nitre, with salt, sulphate or carbonate of soda, carbonate of ammonia, etc., which were supposed to improve the combustion, prevent smoke and slag the ashes; that they were valueless, as the amount of nitre was too small to do any good, as only three pounds of powder is used, while the trouble with our ashes is that they are too fusible already, and hence clinker on the grate bars: stated that the work of the committee had resulted in creating a demand for better designed boilers and greater care in operating, besides abating the smoke; that more care was being exercised in selecting fuels, and that probably coal would soon be sold on

the basis of heat units capacity in this market. Stated that the steam jet principle was usually quite effective in preventing smoke, but generally at a slightly increased consumption of fuel; cited a case, however, where an economy of eighteen per cent. had been attained with a steam jet where a bed of fifteen inches was carried on a hard worked boiler, though when the thickness was increased to twenty or lessened to eight inches there was a loss in economy and capacity; that the down-draught type was not only effective in preventing smoke, but increased the efficiency and economy of the plant, and that forty to forty-five pounds of coal per square foot of grate surface, with a good draught, or fifty pounds with strong draught, could be burned on down-draught grate-bars. Stated that the Wabash Railroad was successfully preventing smoke on its locomotives by a combination of a steam jet and a baffle arch, which latter did away with the excessive noise of the jet. Stated that a new down-draught device had been brought out in London, England, for domestic stoves and ranges that was quite successful, and which promised to solve the smoke problem from dwellings, but that smokeless fuels, like coke, anthracite, oil and gas were already available, which not only prevented smoke, but were much cleaner, and that crushed coke was but little more expensive than coal.

The paper was discussed by Messrs. Brunner, Colby, Prof. Johnson, Bryan, Moore, Prof. Wheeler and Prof. Kinealy, in which Mr. Bryan stated that the extra expense of adding a down-draught device to a 100 horse-power plant was about $800, while Mr. Moore added that an economy of about twenty-three per cent. in fuel would thereby be saved. Prof. Potter stated that no ordinary grate-bars would satisfactorily prevent smoke, over long periods, where the care of the fireman had to be depended on, no matter how slow the rate of combustion.

Adjourned. H. A. Wheeler, Secretary pro tem.

389th Meeting, December 6, 1893. The Club met at 8 p. m., December 6, 1893, at Washington University, with President Moore in the chair and thirty members present.

In the absence of Mr. Thacher, Julius Baier was appointed Secretary pro tem.

The minutes of the 388th meeting were read and approved.

The action of the Executive Committee at their 151st meeting was reported.

In the absence of the Secretary, his annual report was postponed till next meeting.

The report of the Treasurer was read and accepted.

The committee on entertainment of visiting engineers reported and were discharged.

The committee on nominations made the following report:

"After mature deliberation and consultation with a number of the members, your committee on nominations has deemed it wise to depart from precedent to the extent of submitting two names for each office, in order that voters may have a choice. We beg, therefore, to submit the following:

"For President—B. L. Crosby, N. W. Eayrs.

"For Vice-President—Chas. W. Melcher, Julius Pitzman.

"For Secretary--Arthur Thacher, H. A. Wheeler.

"For Treasurer—J. H. Kinealy, Otto Schmitt.

"For Librarian—T L. Condron, A. L. Johnson.

"For Directors (two to be chosen)—Edward Flad, E. A. Hermann Robert Moore, J. A. Ockerson.

"For Members Board of Managers (two to be chosen)—C. W. Clark, J. B. Johnson, S. B. Russell, Wm. Wise."

The report was accepted and the committee discharged.

The following additional nominations were made:

For Vice-President—S. B. Russell.

For Secretary—Wm. H. Bryan.

For Treasurer—Chas. W. Melcher.

The application of Henry L. Reber for membership was presented and referred to the Executive Committee.

The committee on local data was discharged.

It was moved and carried that all special and standing committees be notified to report at the next meeting.

The Executive Committee was authorized to arrange for a dinner at the next meeting.

The paper of the evening, by Prof. J. H. Kinealy, on "The Ratio of Fuel Burned per Hour to Heating Surface for Minimum Yearly Expense of Plant," was then read. Prof. Kinealy used Rankine's formula, showing the relation between efficiency of evaporation, heating surface and grate surface, and deduced an expression for the cost of plant per square foot of heating surface, and also an expression for the cost of coal used in terms of heating surface. A fractional part of the initial first cost of plant, representing interest, repairs and depreciation, with the cost of coal per year plus a constant for attendance, represented the total yearly expenses of the plant; then solved this equation for the value of the number of pounds of coal burned per square foot of heating surface per hour to make the total yearly cost a minimum; showed that this depended simply upon the sum per year covering interest, repairs and depreciation, and the coal bill, and that where the former was large compared with the latter, capacity of plant is of more importance than efficiency of combustion: also, where the former is small as compared with the latter, economy of combustion becomes of more importance than capacity of plant; showed curves indicating the change in economy of combustion and capacity of plant for changes in rate of combustion, also curves showing how the first cost of boiler plant, not including cost of land, varied with the number of square feet of heating surface.

The paper was discussed by Prof. Johnson, Messrs. Bryan. Laird and McMath.

Adjourned. JULIUS BAIER, Secretary, pro tem.

390TH MEETING, DECEMBER 20TH., 1893. The club met at 7:30 p. m. at the Mercantile Club, and after partaking of supper President Moore called the meeting to order with forty-four members present.

The minutes of the 389th. meeting were read and approved.

The Executive Committee reported the doings of the 152nd. meeting.

Upon motion the election of members was postponed.

The Secretary presented the following Annual Report:

ST. LOUIS, MO., December 6, 1893.

TO THE MEMBERS OF THE ENGINEER'S CLUB OF ST. LOUIS.—

GENTLEMEN: The records of the club show the following statistics for the past year: Sixteen meetings have been held, thirteen at the Odd

Follow's building, one at the Mercantile club and two at Washington University. President Johnson occupied the chair at one meeting. President Moore at fourteen and Vice-President Crosby at one. The total attendance of members was 410, or an average of twenty-six. We have also had with us twenty-seven visitors. The total number of meetings is now 388. Papers have been presented by Messrs. Eayrs, Ferguson, Hermann, Howe, Johnson, Kinealy, Moore, Molitor, Palfrey, Pegram, Potter and Schaub. The club has lost eight members by resignation and five have been dropped for non-payment of dues. Seven new members have been elected. The present roll of the club shows we have 136 resident members, forty-three non-resident members and one honorary member, or a total of 180. Respectfully submitted, ARTHUR THACHER.

The report was accepted.

The Committe on Monument to James B. Eads reported progress. On motion the report was accepted and the committee continued.

The Committee on Smoke Prevention reported progress. On motion the report was accepted and the committee continued.

The Committee on Future Permanent Quarters reported. On motion the report was accepted and the committee discharged.

The President presented a proposition from the Missouri Historical Society offering Quarters in their building on Lucas Place. On motion the Executive Committee were empowered to negotiate with the Historical Society, at a rental not to exceed $400 per year and an additional sum of $50 per year for services of secretary of the Historical Society.

The result of the election of officers was announced as follows:

President—B. L. Crosby.

Vice-President—S. B. Russell.

Secretary—Wm. H. Bryan.

Treasurer—Chas. W. Melcher.

Librarian—T. L. Condron.

Directors—Edward Flad and Robert Moore.

Members Board of Managers—J. B. Johnson and S. B. Russell.

After the result had been announced Mr. Moore called Mr. Crosby to the chair. Mr. Crosby thanked the club and called on the retiring president for the annual address.

Mr. Moore reviewed the work in engineering for the past year. Adjourned. ARTHUR THACHER, Secretary.

BOSTON SOCIETY OF CIVIL ENGINEERS.

NOVEMBER 15TH, 1893:—A regular meeting was held at the Society rooms, 36 Bromfield Street, Boston, at 7:50 o'clock p. m.

President Freeman in the chair. Fifty-eight members and twenty-five visitors present.

The record of the last meeting was read and approved.

Messrs. Percy L. Barker and Adelbert K. Sprague were elected members of the Society.

The Secretary read communications from the Austrian Society of Engineers and Architects and from the German Engineering Society, expressing the thanks of those Societies to the several American engineering societies which had maintained the headquarters at Chicago during the World's Fair.

On motion of Mr. Main the thanks of the Society were extended to the Boston Rubber Shoe Company for courtesies shown the members on the occasion of the visit to its works.

Mr. George A. Kimball for the committee appointed to prepare a memoir of the late Augustus W. Locke submitted its report. Mr. Henry Manley added a few words to what had been said by the committee regarding Mr. Locke, expressive of the severe loss which he felt in his death and of the good which he had derived from his acquaintance with Mr. Locke.

In the absence of the author, the Secretary read a paper by Mr. Arthur W. Hunking, entitled "Notes on Water Power Equipment and Considerations Affecting the Selection of the Turbine."

Prof. Dwight Porter read a short paper outlining the course of instruction at the Massachusetts Institute of Technology on the construction of turbines. In the discussion which followed, President Freeman and Messrs. F. S. Hart and Franklin L. Pope took part.

At the close of the literary exercises the members examined the exhibit of surveying instruments which Messrs. Buff & Berger of Boston had kindly placed on the platform. The exhibit comprised the whole of the very extensive display made by this firm at the World's Fair in Chicago and contained many interesting novelties. Mr. Berger very kindly explained some of these special features.

Adjourned. S. E. Tinkham, Secretary.

WESTERN SOCIETY OF ENGINEERS

309th. Meeting, December 6, 1893. The 309th. meeting of the Society was held at No. 10 Van Buren Street, December 6, 1893, at 8 p. m. President Robert W. Hunt in the chair, and 35 members and guests present.

The reading of the minutes of the last meeting was dispensed with.

The report of the Board of Directors included the election of Mr. Francis H. Bainbridge to membership.

Applications were received from Messrs. Virgil Gay Bogue, Alfred Noble, Henry Goldmark and James H. Brace.

Bills to the amount of $46.00 were ordered to be paid.

The report of a committee of the Board of Directors on "The Tenure of Office of the Managers Representing this Society in the Association of Engineering Societies," and "On the Conditions and Terms of the Agreement Existing Between this Society and the Board of Managers of the Association of Engineering Societies," was presented to the Society.

The President stated that in connection with the report an amendment to the by-laws would be offered, after the disposal of the amendment now before the Society for action.

The amendment to the by-laws presented at the October meeting was voted upon and carried.

The President next offered the following amendment to the by-laws concerning the relations of the Society with the Association of Engineering Societies.

PROPOSED AMENDMENT TO BY-LAWS.

ARTICLE VII.

Insert an additional section which will read as follows:

Section 3. The Board of Directors shall annually at the first meeting after the annual meeting of the Society elect the managers who shall represent this Society in the management of the Associated Engineering Societies: which managers shall hold office for one year and until their

successors are elected, and shall be eligible for reappointment. Any vacancy among these managers shall be filled by the Board of Directors.

The above will come up for action at the February meeting of the Society.

The President called the attention of the Society to the annual meeting and read the by-laws relating to the election of officers.

The following were appointed a committee on arrangements for the annual meeting.

Willard A. Smith, Horace E. Horton, Ralph Modjeski.

There being no further business the President called for the paper of the evening on "The Reconstruction of the Burlington Bridge," by Mr. George S. Morison, which was read by Mr. E. Gerber.

By request Mr. Gerber also read the specifications governing the work.

The paper was accompanied by blue prints and photographs, and other facilities for readily following the details as presented.

Adjourned. JOHN W. WESTON, Secretary.

CIVIL ENGINEERS' CLUB OF CLEVELAND.

DECEMBER 12TH, 1893. Meeting called to order at 7:50 o'clock by the President. 33 members and visitors present.

The records of meeting of November 14 were read and approved.

The applications of Messrs. E. A. Handy and C. A. Carpenter for active membership were read.

Letters were read from Mr. Ryerson Ritchie, Secretary Chamber of Commerce, acknowledging request for the use of the Chamber of Commerce Rooms for the December meeting, which request was very cheerfully and unanimously granted.

The President announced the substitution of the name of Mr. N. P. Bowler on the committee to draft resolutions on the death of John H. Sargent in place of John F. Brown, resigned.

It was moved and carried that the Secretary be instructed to write the Chamber of Commerce, extending the thanks of the Club for the use of their rooms.

Mr. L. E. Chapin, of Canton, Ohio, then presented the paper of the evening entitled, "Sewage Disposal at Canton, Ohio," which was discussed by Messrs. E. P. Roberts, Hosea Paul, C. M. Barber, W. H. Searles and A. H. Porter.

Adjourned. FRANK C. OSBORN, Secretary.

INDEX DEPARTMENT.

ANNUAL SUMMARY.

It is proposed to furnish, in this department, as complete an Index as may be of current Engineering Literature of a fragmentary character. A short note will be appended to each title, intended to give sufficient information to enable the reader to decide whether or not it is worth his while to obtain or consult the paper itself. The Index will be mostly limited to society and magazine articles, and special engineering reports of general interest and value. It is printed in the monthly issues of the JOURNAL, *but on one side of the paper, so that the titles may be cut out and pasted on cards or in a book, and is here collected with additional cross references.*

LIST OF PERIODICALS INDEXED.

Age of Steel (*Age of Steel*), weekly, Equitable Building, St. Louis, Mo.; per year, $3.

American Architect (*Am. Arch.*), weekly, Ticknor & Co., 211 Tremont street, Boston, Mass.: single copy, 15 cents.

American Engineer and Railroad Journal (*Am. Eng. & R. R. Jour.*), monthly, 47 Cedar St., New York: per year, $3; single copy, 25 cents.

American Machinist (*Am. Mach.*), weekly, 96 Fulton street, New York; per year, $2 00; single copy, 10 cents.

American Manufacturer and Iron World (*Am. Mfr.*), weekly, Pittsburg, Pa.; per year, $4; single copy, 10 cents.

Annales des Ponts et Chaussees (*Annales des P. & C.*), monthly, Vve. Ch. Dunod, 49 Quai des Augustins, Paris, France.

Electrical Engineering (*Elec. Engineering*), monthly, 565 The Rookery Building, Chicago, Ill.: per year, $3; single copies, 25 cents.

Electrical Review (*Elec. Rev.*), weekly, 22 Paternoster Row, London, E. C.; per year, 21s. 8d.; single copy, 4d.

Engineering Record (*Eng. Rec.*), weekly, 277 Pearl street, New York: per year, $5; single copy, 12 cents.

Engineering News (*Eng. News*), weekly, Tribune Building, New York; per year $5; single copy, 15 cents.

Engineering and Mining Journal (*E. & M. Jour.*), weekly, 27 Park Place, New York; per year, $5.; single copy, 15 cents.

Engineering (Lon. *Eng.*), weekly, London, England; per year, $10; single copy, 25 cents.

Indian Engineering (*Ind. Eng.*), weekly, Calcutta, India; 18s. per year; single copy 8 annas.

Journal of the Association of Engineering Societies (*Jour. Assn. Eng. Soc.*), monthly, Lakeside Building, Chicago; per year, $3; single copy, 30 cents.

Journal of the Franklin Institute (*Jour. Fran. Inst.*), monthly, Franklin Institute, Philadelphia, Pa.; per year, $5; single copy, 50 cents.

Journal of the New England Water Works Association (*Jour. N. E. W. W. Assn.*), quarterly, New London, Conn.: per year, $2; single copy, 75 cents.

Journal of the Society of Arts (*Jour. Soc. Arts*), weekly, London, England; single copy, 6d.

Kansas University Quarterly (*Kansas Univ. Quart.*), Lawrence, Kansas; single copy, 50 cents.

Locomotive Engineering (*Loc. Eng.*), monthly, 5 Beekman Street, New York; per year, $2; single copy, 20 cents.

Mechanics (*Mechanics*), monthly, 430 Walnut Street, Philadelphia, Pa.; per year, $1; single copy, 10 cents.

Paving and Municipal Engineering (*Pav. & Munic. Eng.*), monthly, Municipal Engineering Co., 44 Chamber of Commerce, Indianapolis, Ind.; per year, $2; single copies, 25 cents.

Power (*Power*), monthly, World Building, New York; per year, $1; single copy, 10 cents.

Proceedings of the Engineers' Club of Philadelphia (*Proc. Eng. Club Phila.*), quarterly, 1122 Girard St., Philadelphia, Pa.; per year, $2.

Proceedings of the Institution of Civil Engineers (*Proc. Inst. C. E.*), 25 Great George St., Westminster, S. W. London, Eng.

Proceedings of the Institution of Mechanical Engineers (*Proc. Inst. Mech. Engrs.*), 19 Victoria St., Westminster, S. W. London, Eng.

Proceedings of the United States Naval Institute (*Proc. U. S. N. I.*), quarterly, United States Naval Institute, Annapolis, Md.; per year, $3.50; single copy, $1.

Railroad Gazette (*R. R. Gaz.*), weekly, 73 Broadway, New York; per year, $4.20; ingle copies, 10 cents.

Railway Review (*Ry. Rev.*), weekly, The Rookery, Chicago, Ill.; per year, $4.

Scientific American Supplement (*Sci. Am. Sup.*), weekly 361 Broadway, New York; per year, $5; single copy, 10 cents.

Scientific American (*Sci. Am.*), weekly, 361 Broadway, N. Y.; per year, $3

School of Mines Quarterly (*Sch. Mines Quart.*), Columbia College, New York City; per year, $2; single copy, 50 cents.

Street Railway Journal (*St. Ry. Jour.*), monthly, World's Building, New York; per year, $4; single copy, 35 cents.

Street Railway Review (*St. Ry. Rev.*), monthly, 269 Dearborn st., Chicago, Ill.; per year, $2; single copy, 25 cents.

Technology Quarterly and Proceedings of the Society of Arts (*Tech. Quart.*), Mass. Inst. Technology, Boston, Mass.; per year, $3.

The Electrical Engineer (*Elec. Engr.*), weekly, 203 Broadway, New York; per year, $3; single copy, 30 cents

The Electrical World (*Elec. World*), weekly, 177 Times Building, New York. per year, $3; single copy, 10 cents.

The Engineer (Lon. *Engineer*), weekly, London, England; per year, $10; single copy, 25 cents.

The Engineering Magazine (*Eng. Mag.*), monthly, 47 Times Building, New York. per year, $3; single copy, 25 cents.

The Inland Architect and News Record (*Inland Arch.*), monthly, The Inland Publishing Co., 19 Tribune Building, Chicago; per year, $5; single copies, 50 cents. Photo-gravure Edition; per year, $10; single copy, $1.

The Irrigation Age (*Irrigation Age*), monthly, Chicago, Ill.; per year, $2.

The Journal of Railway Appliances (*Jour. Ry. Appli.*), monthly, 35 Warren St., (Para Building), New York; per year, $2 single copy, 25 cents.

The Locomotive (*Locomotive*), monthly, Hartford, Conn.; per year, 50 c nts.

The Mechanical World (*Mech. World*), weekly, Manchester, England; per year, 8s. 8d.; single copy, 1 penny.

The Newspaper Agency, 19 Spring Gardens, London, England.

The Railway Engineer (*Ry. Eng.*), monthly, 8 Catherine St., Strand, W. C., London, Eng.; single copy, 1 s.

The Railway Master Mechanic (*Mast. Mech.*), monthly, "The Rookery," Chicago Ill.; per year, $1; single copy, 10 cents.

The Street Railway Gazette (*St. Ry. Gaz.*), monthly, Phoenix Building, Chicago; per year, $2; single copy, 25 cents.

Transactions American Institute of Electrical Engineers (*Trans. A. I. E. E.*), 12 West 31st St., New York City.

Transactions American Institute of Mining Engineers (*Proc. A. I. M. E.*), 13 Burling Slip, New York; per year, $5.

Transactions American Society of Civil Engineers (*Trans. A. S. C. E.*), 127 East Twenty-third street, New York; per year, $10

Transactions American Society of Mechanical Engineers (*Trans. A. S. M. E.*), 12 West 31st Street, New York.

Transactions Canadian Society of Civil Engineers (*Trans. Can. Soc. C. E.*). Sec'y., McGill University, Montreal.

Transactions of the Technical Society of the Pacific Coast (*Trans. Tech. Soc. Pac. C.*) Rooms 14-15, 408 California street, San Francisco, Cal.

Aerial Navigation. *Recent Advances made toward the Solution of this Problem.* Review of methods and success attained by the leading investigators, Horatio Phillips, H. S. Maxim and Prof. Langley. *Eng. Rec.*, April 22, 1893, pp. 411-12.

———. *The Mechanics of Flight and "Aspiration."* Paper by Mr. A. M. Wellington, before the Conference of Aerial Navigation at Chicago, Aug., 1893, giving an attempted explanation of the soaring of birds, and how they take energy from the wind and use it to obtain a higher elevation. Application of this principle as a means of propulsion in the normal flight of birds. Longitudinal and transverse stability and manner of obtaining buoyancy. *Eng. News*, Oct. 12, 1893, pp. 286-287 and 295. *Eng. News*, Oct. 26, 1893, p. 335.

Air. *Some Foreign Methods of Air Moistening and Ventilating.* Details and description of several ingenious devices which have given good satisfaction. *Eng. Rec.*, June 3, 1893, p. 13.

———. *Measurement of the Velocity in Pipes.* Paper by Bryan Donkin before Inst. C. E. Comparison of values obtained by anemometers, measurements with actual velocities calculated from change in volume of a gas-holder tank. Experiments in cast iron pipes 8 in. to 24 in. in diameter. *Eng. News*, Dec. 22, 1892, pp. 584-5.

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